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War. Dept. Ordnance Bureau

Ordnance memo #8

W34.10:8^{2}

METALLIC AMMUNITION

FOR THE

SPRINGFIELD BREECH-LOADING RIFLE-MUSKET.

PREPARED UNDER THE DIRECTION OF THE CHIEF OF ORDNANCE

BY

OFFICERS OF THE ORDNANCE DEPARTMENT,
U. S. ARMY.

Ordnance Memoranda No. 8,

NEW EDITION, REVISED AND ENLARGED

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FRANKFORD ARSENAL,
PHILADELPHIA, PA.,
July 1, 1870.

Bvt. Major General A. B. DYER,
Chief of Ordnance, Washington, D. C.

GENERAL:

In obedience to your instructions of the 19th of April, 1870, directing me to furnish additional data in relation to the manufacture of metallic ammunition, &c., I have the honor to submit the accompanying manuscript and drawings.

While, in handling the subject, it has taken a somewhat larger scope than was originally expected, it is, nevertheless, believed that most, if not all, the matter furnished will prove of great interest to the officers of the corps and others who, from the varied nature of their duties and stations, can only learn of progress in specialties through the published Memoranda of the Department.

In preparing the manuscript I have been largely assisted by Captain J. P. Farley, Ordnance Corps, who has made, with great care, perspective drawings of all the machines employed at this Arsenal in the manufacture of metallic ammunition, of the firing rest, its slides, etc., in use at the firing house, and a beautiful drawing showing clearly the manner of recording targets and some general features of the firing ground. Also, by Captain William Prince, Ordnance Corps, in the preparation of his clear description of the arrangements of the firing house, firing ground, targets, the various apparatus employed in their connection, etc., and a very clear and interesting reduction and compilation of the results of many of the most interesting experiments with small arms, ammunition, etc., conducted under his charge.

In submitting these papers, I respectfully recommend, if it meets the views of the Department, that they be embodied in a new edition of Ordnance Memoranda No. 8.

Very respectfully, your obedient servant,

T. J. TREADWELL,
Bvt. Lieut. Col. Commanding.

[*Letter of Bvt. Lieut. Col.* S. V. BENÉT *which prefaced the original edition of Ordnance Memoranda No.* 8, *of* 1868.]

FRANKFORD ARSENAL,
PHILADELPHIA, PA.,
May 13, 1868.

Bvt. Maj. Gen. A. B. DYER,
Chief of Ordnance, Washington, D. C.

GENERAL:

The manufacture of metallic-case cartridges for the Springfield breech-loading rifle-musket, caliber .50, was undertaken at this Arsenal in compliance with your instructions to me of October 5, 1866. At that period our experience was limited to the production of a few experimental cartridges at the Armory and at this Arsenal, with deficient machinery and unskilled labor.

The cartridge adopted and ordered to be made was the MARTIN CENTER-FIRE, the percussion composition being held in the cavity of a straight bar of tinned iron pressed closely against the head of the case. Although not then in its perfected state, the arrangement gave undoubted evidence of great superiority, and its subsequent success has proved the wisdom of its adoption by the Department.

In carrying out your instructions, extended experiments were made to determine the best quality of material to be used, the proportions of the different parts of the cartridge case and anvil, the surest and safest process for accomplishing the most perfect work, and the condition and efficiency of the finished cartridge. These trials had to be prosecuted *pari passu* with the designing and building of special machinery to perform with economy the most exact and delicate operations, and, with the actual manufacture of the ammunition itself to meet the wants of the troops that were about to be armed with the new weapon. And yet the reports from company commanders in garrison and in the field are conclusive as to our success in providing a superior cartridge for the service.

Attention was, however, early drawn to the necessity of reinforcing the head of the case where its weakest point is subjected to the severest strain, and where its bursting would endanger the stability of the breech arrangement. Bvt. Col. J. G. BENTON, Ordnance Department, suggested the use of a thin copper cup in combination with the bar anvil, the cup acting as a reinforce to resist the first action of the powder and fulminate and render the yielding of the head impossible. There were two objections to its adoption: the liability to miss-fires from having two thicknesses of metal in the head, and the increased difficulty and expense of manufacture due to its complication. I thought it possible, however, that the cup itself might be made to perform the additional work of the anvil and thus overcome the objections by dispensing with the bar. After repeated trials with cups of different metals and forms, the one made of sheet tinned iron was found to possess all the qualities required and has been adopted. No doubt exists of its being a marked improvement, and frequent firings, with charges varying from seventy to one hundred grains of strong rifle powder, show its strength to resist far heavier strains than any to which it can be subjected by the largest charges used in service.

For the information of the Department I have the honor to append a description of the mode of manufacture, with records and results of such trials and experiments as have been made, from time to time, to test the efficiency and reliability of the work done.

Very respectfully, your obedient servant,
S. V. BENÉT,
Bvt. Lieut. Col. Commanding.

THE CENTER-FIRE METALLIC-CASE CARTRIDGE.

The successful invention of the self-primed metallic-case cartridge has greatly simplified the construction of breech-loading small arms. Prior to its introduction and use, the prevention of the escape of flame through the joint of the breech was of difficult if not impossible accomplishment, and complicated arrangements of the breech mechanism had to be resorted to with at best unsatisfactory results. The metallic cartridge overcomes this difficulty, being itself a perfect gas-check renewed at every round, prevents foulness and wear of the mechanism, and exercises the most vital functions in the life of the arm. So important an element is it that it may be said that, with a perfect cartridge, the most indifferent breech arrangement can be used with safety and efficiency.

Its advantages, other than that already indicated, are many; its completeness and simplicity, being self-primed, and used as a whole in loading; its strength and safety, withstanding the roughest usage and thoroughly protecting the powder and fulminate; its accuracy, because of the coincidence of the axes of the bore and bullet; and, added to these, the absolute impossibility of using more than one cartridge at a time.

That adopted by the Ordnance Department is known as the CENTER-FIRE. The superiority of this system over the rim-fire is so marked as will undoubtedly lead to its universal adoption. By concentrating the percussion composition in the center of the head the quantity used is reduced to a minimum, to less than one-fourth of what is required to prime the entire circumference in the rim-fire, and this smaller quantity is so much better protected as not to be at all liable to accidental explosions. The central portion of the head has more elasticity than the rim, and is better able to resist the strain upon it from the sudden action of the fulminate, besides having the additional advantage of permitting the reinforcing of the rim, thus strengthening the weakest portion of the cartridge case.

The U. S. regulation center-fire metallic cartridge consists of the following parts, viz.:

The CASE.
The CUP ANVIL.
½ grain of PERCUSSION COMPOSITION.
70 grains of MUSKET POWDER, and—
A lubricated LEADEN BULLET weighing 450 grains.

The case is the copper tube which forms the receptacle for the powder charge, the percussion composition, and the leaden bullet. Its exterior conformation is designed to facilitate its ready extraction from the chamber of the gun after firing. Besides the rim at the closed end, which is intended primarily to assist extraction, the case is tapered from the rear to a point where it siezes the bullet, whence it merges into a right cylinder.

The cup anvil is a small metallic cup, of sufficient rigidity to resist the blow of the hammer communicated by the firing pin, and of such form as to insure the passage of the flame to the powder charge upon the explosion of the percussion composition. It is provided with a circular recess or cavity into which the percussion composition is deposited. Two little vents, at the extremities of a diameter of this recess, direct the flame to the charge. The cup, when charged with the composition, is placed within the copper case, pressed snugly against its closed end, and crimped firmly into position. Cups were formerly made of sheet-iron tin-plate, but they are now made of copper.*

The bullet enters more than half its length into the case, in order that the lubricant in its grooves may be entirely covered and protected. To render the cartridge water-proof, the edge of the case is crimped hard against the bullet.

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THE CASE.

THE COPPER.

The sheet copper for making the cases is No. 22, wire gauge, obtained in strips 35 inches long, 3.3 inches wide, and from .025 to .027 inch thick. The ends of these strips are cut at an angle to avoid waste, and each strip gives material for 40 cases, with one-fourth scrap.

In the selection of sheets for making the cases, such only should be chosen as appear to have been rolled in a careful manner. They must be free from any the slightest seams, blisters, or flaws, and of an even thickness throughout, well annealed, and trimmed to the foregoing dimensions.

The best copper ores are mined on the shores of Lake Superior. The "Minnesota Mines," and the most approved brands of "Detroit" smelting, should be selected in preparing metal for cartridge purposes.

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*See "CHEMICAL AND VOLTAIC ACTION."

Most of the copper heretofore used at Frankford Arsenal has been procured from the mills at Bloomfield, N. J. It is not pure, as received from the mills, being alloyed with 5 per centum of spelter.

DOUBLE ACTION PRESS.

The first operation in drawing the tubes is peformed by the Double Action Press.

The strips of copper are prepared for the press by straightening their ends and edges, if necessary, with a hand mallet, and oiling both surfaces. The strips are then fed to the press by hand, a small stop on the die-plate regulating the length of feed.

The first shape given to the future cartridge case is that of a flat circular disk, 1.7 inch in diameter, cut from the copper strips fed under the double-punch of this press. This punch is essentially a punch within a punch; the exterior one cutting the disk clear from the strip, while the interior one descends and forces it through a tapered die, giving it a shallow, cup shape, 1.06 inch in diameter, and .55 inch deep. After passing through and beyond the tapered die, the cup expands slightly, and is stripped from the interior punch as the latter ascends.

Two rows of disks are cut from each strip, one disk at a time. They are cut and cupped at the rate of seventy-five a minute. Experience has proven that a width of strip giving only two rows of disks is better than a width giving three or more rows, the former being rolled to a more uniform thickness and subject to less percentage of waste.

SINGLE ACTION PRESSES.

In order to draw the cups to the dimensions required for the finished cases, they are subjected to the action of four additional punches and dies of decreasing sizes, so as to gradually elongate the cups while reducing their diameters. These draws are made by Single Action Presses, having each a single punch and die.

The first press elongates the cup to .96 of an inch, and reduces its diameter to .81 of an inch.

The second press elongates it to 1.3 inch, and reduces the diameter to .69 of an inch, thus lengthening out the cup into a tube.

These tubes, at this stage, are annealed after a process to be presently described.

The third press elongates the tube to 1.52 inch, and reduces its diameter to .60 of an inch.

The fourth press brings the tubes to the required exterior diameter of .50 of an inch, the extreme permissible variation of which is .002 of an inch; but they are left of unequal lengths and with ragged edges.

These presses are fed at the rate of sixty-five tubes a minute, by placing them upright on a revolving horizontal plate provided with guides and stops.*

ANNEALING.

The tubes are annealed, after the second draw, as stated above, to restore to the metal its ductility, the previous operations having rendered it hard and brittle. The number of annealings required during the entire process of manufacture, will depend on the quality of the metal used; with the best copper only one is necessary. The annealing is done by placing the tubes in a perforated iron cylinder, heating them red hot in a charcoal fire, revolving the cylinder meanwhile to equalize the heat, then plunging them into a solution of one part sulphuric acid and fifteen parts water, and, afterward, thoroughly washing in several changes of water to remove all trace of acid. The acid solution (pickle) is intended to cleanse the metal from any scale, or oxide, occasionad by the annealing.

TRIMMING MACHINE.

The finishing draw having left the tubes of unequal lengths and with ragged edges, it is necessary, in order to facilitate the subsequent steps of manufacture, and insure uniformity in the finished cartridges, to remove the ragged edges, and to reduce the tubes to an uniform length.

This is done by means of the TRIMMING MACHINE. The tubes are placed in the trough of this machine, whence they are taken up by a revolving mandrel, against which, and just inside of a shoulder upon the same, the edge of a circular cutter is pressed. The tube, when brought to position by the mandrel, is cut clean and even by the cutter, a stripper removing the tube and scrap after each operation.

To allow for the metal that is used in forming the head or rim, the tubes are cut a little longer than the headed case.

The tubes are trimmed by this machine at the rate of eighty a minute.

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* Great care must be taken in the preparation of the dies and punches for these presses.

The dies should be made with as hard and smooth a surface as possible, otherwise they will turn out inferior work and wear very rapidly. To prevent them from splitting, they are made hard inside and soft outside, by imbedding them in powdered charcoal in a cast iron box, heating them in a furnace to a cherry red, then passing a stream of salt water through them until cold. (½ bushel salt to 20 gallons water.) The inner surfaces are afterwards smoothed with a lead mandrel, and thoroughly polished with crocus cloth. The very best steel should be used, and American brands are, for this purpose, far superior to the best imported.

The punches are made by being brought to a cherry red in a charcoal fire; Nos. 1 and 2 being then dipped in water, Nos. 3 and 4 in sulphuric acid, and all cooled in oil. The temper is afterward slightly drawn to permit them to be straightened, if necessary.

REMOVING THE OIL.

In all the operations previous to and succeeding the annealing, lard oil of the best quality is the lubricant used. But as the smallest particle of oil will impair the efficiency of the percussion composition, it is of the last importance that all vestiges of it be removed from the interior of the tube before the percussion composition is inserted.

The flattening of the closed end of the tube by the next operation would, if the oil were not previously removed, retain a greater or less quantity of it in the interior fold of the rim, from which no subsequent process could entirely remove it, and from which it would be liable to exude, in the finished cartridge, to the destruction of the percussion composition.

The present unheaded condition of the tube, therefore, affords the most favorable opportunity for removing the oil, which is done by washing the tubes in a solution of 1½ lbs. potash, 1½ lbs. soda, and 5 gallons of water, temperature 120°, for seven minutes, and afterwards rinsing them thoroughly in clean warm water, using a revolving wire barrel partially immersed in it.

HEADING MACHINE.

The head or rim of the cartridge case is next formed by the **Heading Machine.** This machine consists of a horizontal die countersunk at one end for shaping the head; a feed punch to insert the tubes into the die; and a heading punch to flatten the closed end of the tubes into the countersink.

The tubes, which are a little longer than the headed case, are fed into the inclined trough of the Heading Machine, whence they are taken up on the feed punch. A shoulder on this punch, at a distance from its extremity equal to the inner depth of the headed case, prevents it from extending to the full depth of the tube, and a surplus of metal is thereby left at the closed end of the tube for the formation of the head.

The feed punch inserts the tube into the die, and holds it there, while the heading punch moves forward by a powerful cam and presses and folds the unsupported, projecting portion of the tube into the countersink of the die, forming and accurately shaping the head or rim.

The headed case being left in the die as the feed-punch recedes, is pushed out by the succeeding tube, and thrown by a flipper into the receptacle below.

No oil is used in this operation, the moisture of the tubes from the recent washing sufficing as a lubricant.

The machine is fed at the rate of sixty-five per minute.

The cases are now finished; but to be certain that the oil is entirely removed from them, they are again washed in the alkaline solution, and dried thoroughly in a drying room, at a temperature of about 125° Fahrenheit.

THE CUP ANVIL

THE DOUBLE ACTION PRESS.

The cup anvil is made by a DOUBLE ACTION PRESS similar to the one for cutting and cupping the disks for the copper cases.

The best charcoal sheet-iron tin-plate, in strips 18 inches long, 6.25 inches wide, and 0.4 inch thick, was formerly used for making the cup anvils; but recently they have been made from unannealed copper, in strips 20 inches long, 3.125 inches wide, and 0.48 inch thick.

One pound of sheet-iron tin-plate gives one hundred and fifty cups, and five ounces of scrap. One pound of copper gives one hundred and fifteen cups, and six ounces of scrap.

The sheet metal for cups must be free from all defects, with a bright, smooth surface, and uniform in thickness throughout.

The cups are cut and formed by this machine at the rate of seventy-five a minute.

CUP TRIMMING MACHINE.

The cup anvils, as they come from the Double Action Press, are of the right diameter, but too long, and with ragged edges. The cups are reduced to an uniform height by cutting off the ragged edges in the CUP TRIMMING MACHINE, which consists of a revolving rose cutter, made of a number of small cutters that can be changed and sharpened at pleasure.

The cups are fed to the cutters through a vertical trough, and are trimmed at the rate of forty-five a minute.

CUP VENTING MACHINE.

The vents are punched in the trimmed cups by the CUP VENTING MACHINE, which is provided with a two-pointed punch and corresponding dies.

The cups are fed by hand on a revolving circular plate, at the rate of seventy per minute.

CUP IMPRESSION MACHINE.

The circular depression in the bottom of the cup, which serves as the receptacle for the percussion composition, is formed by the CUP IMPRESSION MACHINE.

The cups are fed through a vertical trough at the rate of eighty per minute. The trough has a flat pan at the top, into which the cups in quantities are emptied, and where they are arranged so as to present the proper end to the punch in passing through the machine.

This machine not only forms the recess, but gauges the cup at the same time.

The cups thus completed are well washed in an alkaline solution, to remove all traces of oil, and then thoroughly dried.

RETINNING THE CUPS.

If sheet-iron tin-plate is used for the cup anvils, the cup is next retinned, in order to cover the iron edges left exposed by the Trimming and Venting Machines. This is necessary to prevent deterioration by the moisture of the fulminate.

The tin for this process is prepared by placing "Banca tin," in the pig, into a kettle, and adding a small quantity of rosin while the same is melting, stirring and skimming it until the surface is perfectly clean.

The cups are prepared for the process in the following manner: They are first washed in a solution of soda and potash, (10 ounces each to one gallon of water;) afterwards put into a pickle of 10 parts of water to 1 part of muriatic acid; washed in clean water; shaken in a solution of sal-ammoniac, (1 gallon of water to 4 ounces of sal-ammoniac;) dried and sprinkled with pulverized rosin.

The cups thus prepared are lowered slowly into the melted tin, in a wire basket, where they remain until they are of the same temperature as the tin, when they are taken out and emptied on a clean bench, after being well shaken. The cups are thus recoated with tin, but the deposit is rough and uneven.

The roughness of the tin is remedied in the following manner: The tin in the kettle is purified by skimming it clean, after sprinkling dry saw dust over it to absorb the rosin and other impurities. Tallow enough is then added to cover the tin about one-quarter of an inch deep, and the cups in the wire basket are passed slowly through the tallow two or three times. The basket is then shaken over the kettle and swung several times through the air with a quick jerk to distribute the tin evenly over the surface of the cups; after which the cups are cooled in lard oil. They are then washed in a strong solution of potash and soda, to remove all traces of oil.

One pound of bismuth to each pot of tin will make it flow more evenly over the work.

THE PERCUSSION COMPOSITION.

The Percussion Composition consists of—

Fulminate of mercury,	by weight	35 parts.
Chlorate of potash,	" "	16 "
Glass dust,	" "	45 "
Gum Arabic,	" "	2 "
Gum tragacanth,	" "	2 "

These are mixed without danger by using the fulminate in a moist state, the water having been entirely drained from it. The chlorate of potash being well triturated, and the glass dust properly prepared, the ingredients are put into a China bowl and thoroughly mixed, using a small steel spatula for the purpose. The dissolved gums will contain sufficient water to reduce the composition to a thick paste, it being used in the machine of this consistency.

Glass dust for the percussion composition is prepared for use in the following manner: Broken French *plate glass* only is used. The glass is washed clean and dried; it is then broken into small pieces, put into an iron mill or rolling barrel, running from twelve to fifteen revolutions per minute, and ground for a time; after which it is forced through hair sieves of 40 meshes to the inch to remove the lumps; and what remains is sifted on hair sieves of 140 meshes to the inch to remove the impalpable powder. What is left on this sieve is free from dust and lumps, and is of good grit and ready for use.

PRIMING MACHINE.

The percussion composition of the consistency of thick paste is deposited in the recess of the cup by the Priming Machine—a very ingenious piece of mechanism which performs this important operation with the greatest accuracy and certainty, and with perfect safety.

Its principal parts are: 1st, the central revolving spindle, with four tubular feeders at its head, which deposit the percussion composition in the cups; 2d, the magazine on the right, and 3d, the circular plate on the left, on which the unprimed cups are fed to the machine.

The four tubular composition feeders at the head of the spindle consist each of a small depending stem, down which a closely fitting tube is made to slide—the lower edge projecting a little below the end of the stem. By the revolving motion of the spindle these tubular feeders are brought successively over the magazine and over the cups to be primed.

At the moment a feeder is presented over the magazine, which is a shallow dish containing the percussion composition, the magazine rises until its metal bottom is in contact with the tube, a slight shaking motion of the magazine during its progress serving to deposit compactly into the open projecting end of the tube a sufficient quantity of composition for the priming of a single cup. The magazine then recedes, while the revolving spindle carries the charged feeder to the circular plate on the left, which presents the cups for priming. The motion of this plate is from left to right, while that of the spindle is from right to left, whereby the feeders and cups are made to meet and leave each other in opposite directions. The plate is provided with eight upright movable stems, on the ends of which the unprimed cups are fed.

As the cups and feeders are brought, by the revolutions of the plate and spindle, in a vertical line with each other, the cups are raised by their stems so as to receive the percussion composition exactly in their circular recesses from the tubes of the feeders. The tube, at the moment of contact with the cup, slides up its depending stem and frees the composition from its end, which is pressed, by the upward motion of the cup, snugly into the circular recess. The feeders and cups in parting leave each other horizontally, in opposite directions, so that the percussion composition is sheared off evenly and smoothly with the bottom surface of the cup. A specific quantity of composition is thus deposited in the recess of each cup at each operation.

The principal difficulty heretofore encountered in perfecting a machine of this kind is entirely overcome by the use of this peculiar feeder.

This machine primes at the rate of thirty-five per minute.

TAPERING MACHINE.

While the composition is still moist in the circular recesses of the cups, the latter are put into the headed cases and crimped into position, the cases being tapered at the same time.

This operation is performed by the **Tapering Machine**, which consists of four vertical tapered dies, with stems projecting from their centres on which the cases and cups are fed; the crimpers which work from the sides of the dies; and the descending punch which forces the cases into the dies.

The primed cups are placed on the ends of the stems projecting from the dies, and the cases are placed over them. By the revolution of the horizontal plate on which the dies are placed, each die is in succession brought under the descending punch which forces the cases into the dies, and presses their heads hard against the primed cups, while the crimpers move forward from the side and bite the cups snugly and firmly into place. The central stem rises out of the die as the latter leaves the punch, and the case is removed by a spring.

The section of the case which is to envelop the bullet is not tapered by this machine, it being left in the form of a right cylinder whose inner diameter is the same as that of the bullet. This gives the bullet a securer hold in the case, and helps to make the cartridge water-proof.

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THE BULLET.

THE LEAD.

The United States elongated service bullets are made by compression by means of machinery adapted to this purpose. They are uniform in size and weight, smoother and more homogeneous, more accurate, and give better results than cast and swaged bullets. The lead for bullets should be pure soft lead of commerce, of specific gravity about 11.35, which is increased by pressure to about 11.45, and which melts at 600° Fahrenheit, and volatilizes at red heat.

The lead is first melted and skimmed of dross—amounting to 5 per centum in good lead—and cast in iron moulds into cylindrical bars .59 of an inch in diameter and 20 inches long. These bars are passed through rolls which reduce them to .42 of an inch in diameter and increase their length to 36 inches. The surplus lead, if any, is trimmed off in rolling.

A man will cast, in a day of ten hours, fifteen hundred bars of lead.

A man and boy will roll and trim, in a day of ten hours, three thousand bars of lead.

BULLET MACHINE.

The bars are fed to the BULLET MACHINE through a verticul tube above a horizontal cutter, which cuts, at each stroke, a length sufficient to form a single bullet, and transfers it to the die,* in which, by means of a vertical punch, the bullet is formed with its grooves. The surplus lead is forced out at the junction of the dies, in the direction of the longer axis of the bullet, and at the junction of the punch and dies at its head.

A Bullet Machine will make, in a day of ten hours, thirty thousand bullets.

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* NOTE.—The dies and punches for the bullet machines are made with great care of the best cast-steel. The dies are cut out with cherries to the form and dimensions of the bullet, and have as hard and smooth a surface as it is possible to give them. They are hardened in pure cold water, and the temper drawn to a light straw color. They are made in such a manner that only small portions of their faces just surrounding the base of the bullet may be in contact while the bullet is being formed.

BULLET TRIMMING MACHINE.

The operation of trimming the bullet is performed by the BULLET TRIMMING MACHINE.

The bullets are fed by hand into a revolving perforated circular plate, whence they are forced by a punch through trimmers which open from the point to the base of the bullet, and which conform to its shape, a cutter at the same time passing over the base. After this they are forced by the punch through a gauge under the trimmer.

The bullets do not vary more than one or two grains above or below their prescribed weight.

The best lard oil is used with these machines.

A boy will trim and gauge, in a day of ten hours, fifteen thousand bullets.

THE LUBRICANT.

The LUBRICANT for bullets is made of—

Bayberry tallow, by weight	8 parts.
Graphite, by weight	1 part.

The latter must be of the best quality, and free from grit. The bullets should be lubricated by machinery, whenever possible, as the grooves are more surely and completely filled and more closely packed by mechanical pressure.

Experiment has shown that one of the best lubricants for use with the gun and in the Lubricating Machine is Japan wax. It gives a very small per centum of fouling, and works freely in the machine.

The question of a proper lubricant, however, is still an open one, and further experiments will be made to determine the best lubricant, and with a view to using a larger quantity than can now be held in the *cannelures* of the bullet.

LUBRICATING MACHINE.

The lubrication of the bullet is done by the Lubricating Machine.

The lubricant is moulded into cylinders of about 10 inches in length. These cylinders are fed to the machine through a vertical tube, pressure being applied to keep the supply constant. The bullets are placed by hand in a perforated revolving vertical plate and forced by a punch through a sizing gauge fixed in the bottom of the tube, which is pierced with small holes. The lubricant is forced through these holes into the grooves of the bullet, filling them completely.

In cold weather an arrangement for slightly warming the lubricant should be provided.

A boy will lubricate, in a day of ten hours, fifteen thousand bullets.

LOADING.

LOADING MACHINE.

The cases are now loaded with powder and bullet by means of the Loading Machine, which consists of a revolving circular plate with holes or receivers, and a hopper and powder measure. The cases and bullets are fed on revolving plates, thirty-five a minute; the former are lifted into the receivers, passed under the hopper and measure for a charge of powder, and then under the bullet feeder for a lubricated bullet. In order to insure a full charge in each cartridge the machine is provided with a bell which gives notice to the operative of any failure in this particular. The edge of the case is then crimped on the bullet in a very simple manner. The receivers are smaller at the top where the bullet enters than at the bottom where the case is received, the diameter of the former being only equal to that of the interior of the open end of the latter. After the bullet has been pressed into the case, the cartridge is lifted, so that the edge of the case is forced into the conical surface of the receiver, between its larger and smaller diameters.

Note.—To Mr. Robert Bolton's great practical experience in the management and use of metals, and his painstaking, perseverance, and capacity as master workman in charge, the success of the manufacture of metallic ammunition is largely due.

The priming, tapering, loading, and other special cartridge machines used in the manufacture have been designed by Mr. J. H. Gill, foreman, and built at this arsenal under his immediate supervision. Great mechanical ingenuity and skill have been exercised in their arrangement and construction, and they are believed to be the most complete and efficient machines of the kind known.

The powder is placed in a pasteboard hopper, about two feet above the machine, and is fed to the cases through a paper tube one inch in diameter; the hopper and tube stand inside of a large conical shield of boiler iron.

During the process of manufacture accidents are only possible with the Loading Machine, and, consequently, every precaution has been taken to provide against their occurrence. As the machine is now made and arranged, the explosion of one cartridge may communicate fire to the few charged cases near it without danger. The entire charge of powder in the hopper may be thus exploded without the possibility of injury, either to the operative or to the machine, as the hopper and tube offer but slight resistance to the action of the gases that expend their forces in every direction without affecting the stability of the protecting shield. This has been proved by experimentally exploding full charges of two and a half pounds in the hopper itself. But the explosion of a cartridge in the operation of loading is of very rare occurrence. Out of the many millions loaded at Frankford Arsenal in the past four years, a trifling number only have exploded prematurely, resulting in no damage whatever.

After loading, the cartridges are wiped clean, and put up in paper packages, and packed in wooden boxes for storage or issue.

BLANK CARTRIDGES.

The Blank Cartridge consists of a copper case, 70 grains of musket powder, a cup anvil, ½ grain percussion powder, and a patch of black wax. The copper for blank cartridges is rolled in strips 35 inches long, 3.2 inches wide, and .024 of an inch thick; each strip will cut forty-two disks. The process of manufacture of the cases, etc., is the same as for the ball cartridges up to the point of loading. This is done by boys, by hand, the case being loaded by a charger, and closed by pressing a piece of soft black wax upon the open end. The cartridges are then wiped clean and the waxed end touched with shellac varnish. They are afterward put up in suitable paper boxes, which are packed in wooden boxes for transportation.

The black wax, which is entirely dissipated by firing, is made by boiling for two hours, 15 ℔s. beeswax, and 1 ℔. rosin, in one gallon of pine tar.

PACKING.

The cartridges are put up in paper boxes holding twenty rounds. Each box is arranged for two rows of ten, the rear row being higher than the front, each alternate cartridge having its rim below that of the other, for facility in loading and close packing. The frames and skeleton divisions of the boxes are made of tarred boards, the shapes of each part being cut with punches and dies, and such as require it being creased for folding. The frame of the box is covered with stout paper, bearing a printed description of the contents, and projecting far enough over to paste down the lid securely. For convenience in opening the box a piece of strong twine is fastened at one end of the box, and pasted along the inside of the seam of the lid, the loose end projecting a few inches.

A girl will make, in a day of ten hours, two hundred paper boxes.

The cartridges are packed, for storage or transportation, in wooden boxes containing fifty packages each. These ammunition boxes are painted, and the description of contents is stencil-marked on the ends, the date of fabrication on the sides, and the place of fabrication on the interior of the lid.

CARTRIDGES FOR GATLING GUN.

The cartridges used for the Gatling Gun, caliber .50, is the service rifle-musket cartridge, caliber .50.

The cartridges used for the 1-inch Gatling Gun are of two kinds: an elongated bullet cartridge; and a cartridge of fifteen buck shot in groups of three, with a hemispherical bullet. This ammunition is made by machinery similar (but suited to heavier work) to that used in making the caliber .50 cartridges, except that the long cases require six draws and three annealings, and the short cases five draws and three annealings. The copper is in strips 36 inches long, 6¾ inches wide, and .04 inch thick. One pound will make eight long cases, or eleven short cases; the copper for which latter is 5½ inches wide.

INITIAL VELOCITIES

Of the regulation bullet, with charges of standard musket and rifle powder, made up into center-fire metallic cartridges, and fired from a Springfield breech-loading rifle-musket—measured by the Schultz Chronoscope.

DATE.	ORDER OF FIRE.	CHARGE.	WEIGHT OF BULLET.	INITIAL VELOCITY. FEET.	REMARKS.
April 23, 1868.	1	70 grains musket powder.	450 grains.	1208.7	
	2			1251.2	
	3			1220.5	
	4			1238.7	
	5			1251.2	Mean velocity, 1234 feet.
	1	70 grains rifle powder.	450 grains.	1353.2	
	2			1338.7	
	3			1353.2	
	4			1368.1	
	5			1383.3	
	6			1310.5	
	7			1368.1	Mean velocity, 1353.6 feet.

Rifle powder gives an initial velocity 119.6 feet greater than equal charges of musket powder.

Initial velocities of the regulation bullet with 100 *grains of standard rifle powder, fired from the Springfield breech-loading rifle-musket.*

DATE.	ORDER OF FIRE.	CHARGE.	WEIGHT OF BULLET.	INITIAL VELOCITY. FEET.	REMARKS.
April 28, 1868.	1	100 grains rifle powder.	450 grains.	1659.7	
	2			1682.1	
	3			1716.9	
	4			1682.1	
	5			1716.9	
	6			1728.9	
	7			1648.7	
	8			1637.9	Mean velocity, 1684.1 feet.

Trials were made with these heavy charges of rifle powder, in order to test the strength of the cartridge case as reinforced by the cup anvil. As the initial velocities exceed those with musket powder given in the preceding table by 450.1 feet, the augmented strain on the case, corresponding to these greatly increased velocities, must be very considerable, and yet, only 2 per cent. of the cases burst in the head. The only visible effect on the others was the enlargement of the head and body by less than .01 of an inch. This bursting or enlarging never takes place with service charges. Fifty per cent. of the cartridges made with the straight bar anvil yielded in the head when fired with these large charges, proving the greater strength and consequent security of the cups. The cups may, therefore, be considered a complete protection to the head of the case for all service charges, with a reserve of strength for any unforseen occurrence.

TRIALS OF CARTRIDGES.

During the past years (1867–8) 92,891 metallic cartridges were fired, at this Arsenal, for the purpose of testing the quality of the work as it progressed. They were not selected, but were taken from the daily production after the usual inspection. A considerable proportion of them, however, were such as had been rejected by the inspectors on account of defects in the metal, &c.

79,517	bar anvil cartridges fired, with 68 misses, or one miss-fire out of every 1,169.
13,374	cup cartridges fired, with 7 misses, or one miss-fire out of every 1,910.

Total, 92,891 cartridges, with 75 misses, or ONE TWELFTH OF ONE PER CENT. miss-fires.

These failures were attributed to one of three causes: 1st, the burning out of the percussion composition in the tapering machine, when, through carelessness, it had been permitted to dry before the operation; 2d, the anvil may not have been pressed hard against the head, from imperfect adjustment of the machine; a second blow exploded it; 3d, oil may have got into the composition, the cases not having been entirely freed from it by the potash and soda solution. These several causes of failure were within the means of prevention, and did not militate against the principles of construction followed. It is confidently believed that the cartridge as now manufactured, challenges comparison with the best ever used in any service.

Since March 1, 1868, when the cup anvil was adopted, up to July, 1870, the trials of daily fabrications have given the following results:

No. Fired.	Objects of Firing.	Failures.	Causes of Failures.
32,650	Daily trials	3	1 burst in rim. 1 cut through by firing pin. 1 no percussion powder.
16,875	Various experiments	5	2 bad percussion powder. 3 burst in rim.
49,525		8	

Being eight failures from all causes in 49,525 fires, or *less than one failure in every 6,000 cartridges.*

During the same period there have also been fired, from daily manufactures:

6,250 blank cartridges	No failures.
6,000 Navy blank cartridges	" "
1,150 Navy pistol cartridges	" "

Extract from the report of a trial made at this Arsenal May 6, 1867, *to determine the effect of rough usage on a lot of metallic cartridges packed for issue.*

The wooden box contained one thousand cartridges and weighed one hundred and twenty pounds.

Two men threw the box, from a perpendicular height of ten feet, to some loose planks lying on the hard ground. The box was cracked all round the middle of its height, but the two parts held together sufficiently to keep it in shape.

The box was then tumbled down a stone stairs of fourteen steps, perpendicular height eight feet. The box was broken in two, through the crack previously made.

Upon examination it was found that none of the cartridges had exploded. Twelve of the paper packages had been broken, etc., and the cartridges thrown out, but none of the latter were at all injured externally. To test whether the shocks had disturbed the composition in the anvils, one hundred of the loose cartridges were fired, without a single failure.

On the 21st April, 1868, the following experiment was made to determine whether the explosion of one or more metallic cartridges in a box of ammunition will communicate fire to the remainder:—

A wooden box, packed ready for issue, containing six hundred and eighty metallic cartridges, caliber .50, in paper packages, with the latter in two horizontal layers, was fired into from the 1-inch Gatling gun, carrying a ball weighing seven and a half ounces. Three shots perforated the box and upper layer of paper packages, destroying the upper half of the wooden box, breaking up ten paper packages containing two hundred cartridges, exploding some, bruising and crushing others, and scattering many to a considerable distance. The damage done was as follows:

Twenty-nine cartridges exploded.

Ninety-seven badly bruised and crushed out of shape; some with bullets knocked out and the powder exposed; but none exploded.

Thirty-eight loose, uninjured.

Four hundred and eighty, in paper packages, were uninjured; these included the entire bottom layer.

Thirty-six missing.

The cartridges that exploded were undoubtedly of the number actually struck by the passing ball, but it is a curious fact that so large a proportion should have been subjected to such rough usage with impunity. Although the flame from each of the three explosions was distinctly seen at the distance of two hundred yards, even the paper of the packages was not ignited.

This trial seemed to prove that the explosion of a caisson or an ammunition wagon if not an impossibility is at least robbed of its greatest terrors, by being confined to only a small number of the few cartridges that may be struck by the enemy's shot.

CHEMICAL AND VOLTAIC ACTION.

The metallic cartridge has been subjected to all the vicissitudes of frontier and other transportation and service during the past four years, without apparent deterioration or failure to give satisfaction. Whether time and the constant recurrence of atmospheric changes will eventually destroy the vital force of the percussion composition experience alone can prove. Some of the cartridges made in March, 1867, have recently been carefully examined and fired, and there was no appearance of deterioration in any way. One hundred rounds, selected at random from different boxes, were fired with perfect results. The ammunition of this date, the oldest center-fire on hand, seems to be as good as when it was first made.

A distinguished chemist who, at Col. Benét's request, carefully examined this subject, says:

> "Copper will reduce insoluble mercurial salts when moist and mixed with some suitable chemical agents. Fulminate of mercury, from the little affinity of its component parts for each other, is readily reduced when mixed with chlorate of potash by contact with copper. This reduction is, to a great extent, surface only; when the metallic surface is amalgamated, this further action ceases almost entirely."

The moist composition is used in such small quantities and dries so rapidly that the amalgamating process ceases after very short and feeble action, and the slight reduction of the fulminate of mercury does not affect its explosive qualities either in intensity or sensitiveness. This is established beyond question by the results of our daily experience in the manufacture. Again, he says:

> "The liability to change in the fulminate, when placed on the tinned iron anvil and the cartridge completed, would result from the electro-chemical or voltaic action between the copper case and the tinned iron. This action would be anticipated, as an oxydizing agent (chlorate of potash) lies between the two metallic surfaces, and gunpowder almost always contains sufficient moisture to perfect the voltaic action. Whether the fulminate of mercury would *all* be eliminated or to an extent sufficient to *impair* the detonating character of the compound after long continued action, experiment will alone demonstrate. Absolute results will have to come from a trial of cartridges *several years old.*"

Our limited experience is exceedingly favorable to the use of tinned iron, and nothing has yet been developed leading to the supposition that the cartridge may not remain unchanged an indefinite length of time.

As the moisture of the atmosphere is entirely excluded from the interior of the cartridge the infinitesimal quantity originally in the powder when loaded will hardly be sufficient to do permanent injury, so that even under extraordinary exposure no destructive action is anticipated. A lot of cartridges in 1868 were kept in a very moist atmosphere for four months and one hundred and twenty of them were then fired without a single failure.

A package of each month's manufacture is now placed in a very damp place: atmosphere, dry bulb 71°, wet bulb 70°; also in a warm room: temperature 105°—for future experiments as to the effect on this ammunition of long exposure to moisture and high temperature.

The percentage of failures, when cartridges have been kept under water for many days, is entirely due to their water-proof qualities, which depend on the closeness of the crimping and the kind and quality of the lubricant. That water will eventually make its way into the cartridge under such submersion must be expected, and then a failure is no longer the result of voltaic action but of dissolved gunpowder. Of a number kept under water from one to eleven days twenty rounds were fired daily. The 1st, 2d, and 3d days, no miss-fires; 4th day, one; 5th and 7th days, none; 8th day, five; 9th day, nine; 10th day, ten; 11th day, nine.

Since the above was written, further trials in the use of COPPER cups, with radial ribs on the interior surface to give them the required stiffness to resist the blow of the hammer, have proved satisfactory. We have, therefore, the ready means of avoiding voltaic action by substituting copper for tinned iron, thus using one and the same metal for both case and cup.

July, 1870.—Recent trials have been made with cup anvils of unannealed copper, .045 of an inch thick. Two thousand cartridges with these copper anvils have been fired with perfect success. It is believed that copper is stiff and strong enough for the purpose. The use of copper anvils instead of tin increases the cost price of the finished cartridges about sixty cents per thousand.

MATERIALS REQUIRED FOR 100,000 BULLET CARTRIDGES.

2,632	lbs.	Sheet copper; one-fifth is returned as scrap.
667	"	Sheet tin-plate; one-third scrap.
6,500	"	Lead.
60	"	Lubricant for bullets.
1,000	"	Musket powder.
7.5	"	Percussion composition.
1 126	"	Tarred boards; scrap, 112 lbs.
64	"	Paper covers.
25	"	Paste, (flour for.)
36	lbs.	Nails, 8d.
4	"	Nails, wrought.
900	feet	Boards.
1	lb.	Twine.
8¼	gross	Screws.
15	lbs.	Paint.
1¼	"	Putty.
3	"	Glue.

MACHINES REQUIRED TO MAKE 100,000 BULLET CARTRIDGES A DAY.

NUMBER.	MACHINES.	WORKING CAPACITY OF EACH IN TEN HOURS.
	FOR CASES.	
4	Double action presses	28,000
16	Single " "	26,000
6	Trimming machines	18,000
4	Heading "	26,000
7	Tapering "	16,000
7	Loading "	16,000
2	Annealing furnaces.	
	Wash tubs, barrels, trays, &c.	
	FOR CUPS.	
5	Double action presses	22,000
4	Vent punching machines	28,000
6	Trimming "	18,000
4	Impression "	28,000
7	Priming "	16,000
2	Tinning furnaces.	
	FOR BULLETS.	
4	Bullet machines	28,000
7	" trimmers	16,000
7	" lubricating machines	16,000
2	Sets of rolls.	
	Lead pots, moulds, &c.	
	FOR PAPER BOXES.	
1	Paper cutter.	
2	Creasing machines.	
6	Single presses.	
1	Printing press.	
	Type, &c., wooden formers, paste kettles, brushes, knives, &c.	

MATERIALS REQUIRED FOR 100,000 BLANK CARTRIDGES.

2,381	lbs.	Sheet copper; scrap, one-quarter.	1,028	lbs.	Tarred boards; scrap, 10 per cent.
622	"	Sheet tin; scrap, one quarter.	1	quart	Varnish.
1,000	"	Musket powder.	800	feet	Lumber.
7¼	"	Percussion powder.	4¼	gross	Screws.
143	"	Black wax.	25	lbs.	Paste.
32	"	Nails, 8d.	1¼	"	Putty.
4	"	Nails, wrought.	45	"	Paper covers.
15	"	Paint.	3	"	Glue.
1	"	Twine.			

MATERIALS FOR 10,000 CARTRIDGES FOR GATLING GUN, ONE INCH CALIBER.

1,250	lbs.	Sheet copper, long cartridge; scrap, one-quarter.	15	lbs.	Paint.
910	“	Sheet copper, short cartridge; scrap, one-quarter.	3	“	Glue.
186	“	Sheet tin; scrap, one-quarter.	14½	“	Lubricant.
5,000	“	Lead, for each.	437	“	Tar boards.
470	“	Musket powder.	30	“	Nails, 8d.
11¼	oz.	Percussion powder.	800	feet	Lumber.
45	lbs.	Paper covers.	4	gross	Screws.
¼	lb.	Twine.	1¼	lbs.	Putty.
4	lbs.	Nails, wrought, 2¼.			

DIMENSIONS AND WEIGHTS OF MUSKET CARTRIDGE.

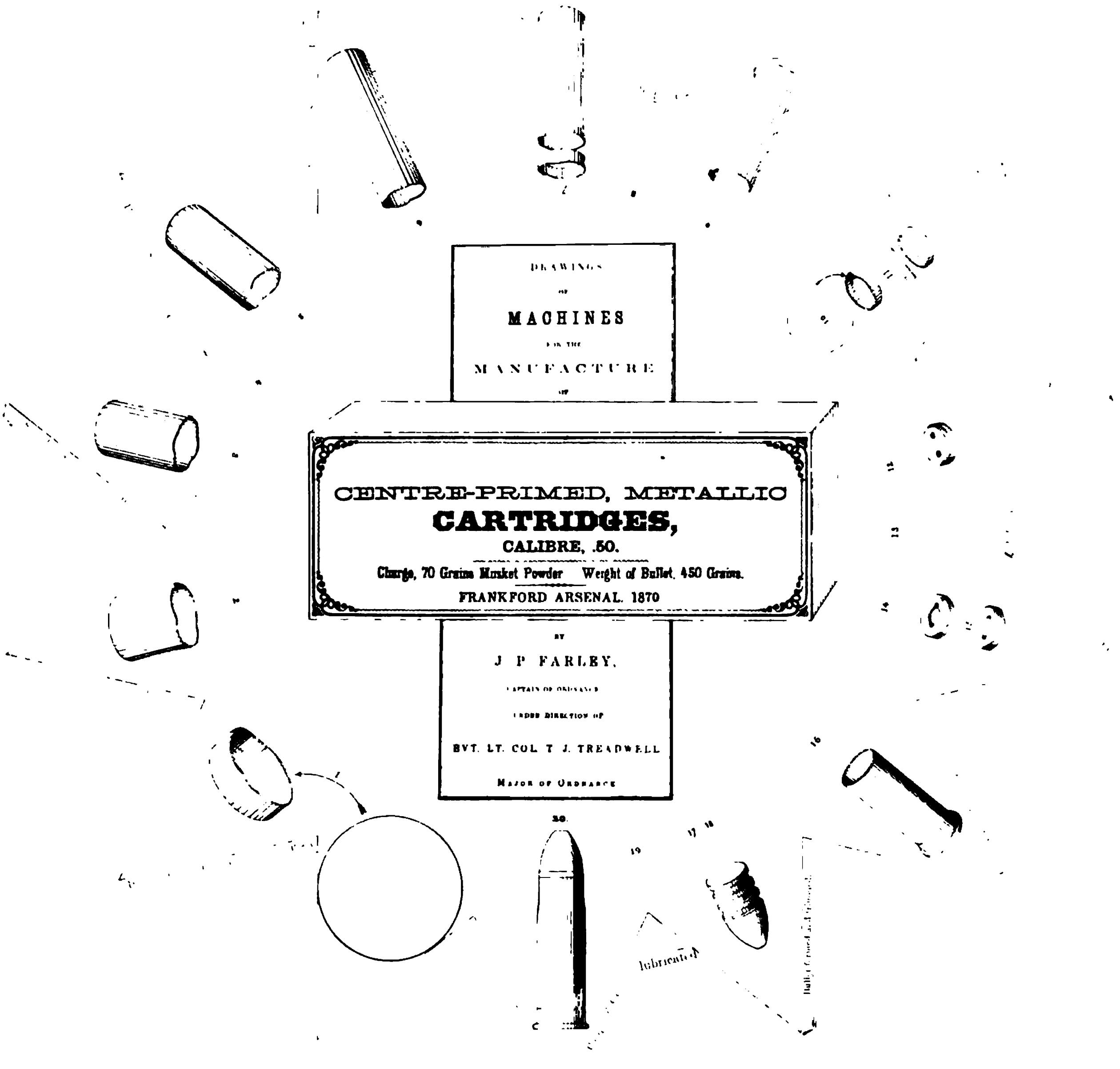
PARTS OF.	TRUE INCH.	MAXIMUM INCH.	MINIMUM INCH.	GRAINS.
CASE.				
Extreme length of case	1.75			
Diameter before tapering		.563	.561	
Diameter under head, after tapering		.563	.561	
Diameter at open end, “ “		.543	.541	
Diameter at head		.665	.660	
Thickness of head	.05			
CUP.				
Height of cup	.20			
Diameter of cup		.527	.526	
Diameter of recess	.15			
Depth of recess	.025			
Diameter of vents	.07			
BULLET.				
Length of bullet	1.00			
Diameter of bullet	.515			
Length of finished cartridge	2.285			
Weight of case				130.
“ “ cup				30.
“ “ powder				70.
“ “ percussion composition				0.5
“ “ bullet				450.
“ “ finished cartridge				680.5
BLANK CARTRIDGE.				
Length of case	1.5			
Weight of case				135.
“ “ finished cartridge				215.

DIMENSIONS AND WEIGHTS OF GATLING ONE-INCH CARTRIDGE.

PARTS OF.	True Inch.	Maximum Inch.	Minimum Inch.	Grains.
Case.				
Extreme length	4.			
Diameter before tapering	1.02			
Diameter of head	1.16			
Thickness of head	.10			
Cup.				
Height of cup	.30			
Diameter of cup	.98			
Diameter of recess	.18			
Depth of recess	.02			
Diameter of vents	.07			
Bullet.				
Length of elongated	1.90			
Diameter of elongated	1.25			
Length of hemispherical bullet	.70			
Diameter of " "	.96			
Diameter of buck shot	.45			
Length of long cartridge	4.60			
Length of short "	3.90			
Weight of long case				687
" " short case				450
" " cup				90
" " powder				325
" " percussion powder				0.5
" " elongated bullet				3,500
" " hemispherical bullet				1,074
" " buck shot				138
" " finished cartridge, long				9 oz. 290 grs.
" " " " short				9 oz. 35 grs.

WEIGHTS OF CARTRIDGES FOR TRANSPORTATION.

Of one paper package containing twenty musket cartridges	2 lbs.	2 oz.
Of one box packed with fifty paper packages, containing one thousand musket cartridges	118 "	4 "
Of one paper package containing twenty blank musket cartridges		12 "
Of one box packed with fifty paper packages, containing one thousand blank musket cartridges	47 "	
Of one paper package containing five cartridges for 1-inch Gatling gun, elongated bullet	3 "	1 "
Of one box packed with twenty paper packages, containing one hundred 1-inch Gatling gun cartridges	70 "	
Of one paper package containing five cartridges for 1-inch Gatling gun, buck and bullet	3 "	2 "
Of one box packed with twenty paper packages, containing one hundred 1-inch Gatling gun cartridges	72 '	



DRAWINGS

OF

MACHINES

FOR THE

MANUFACTURE

OF

CENTRE-PRIMED, METALLIC
CARTRIDGES,

CALIBRE, .50.

Charge, 70 Grains Musket Powder Weight of Bullet, 450 Grains.

FRANKFORD ARSENAL. 1870

BY

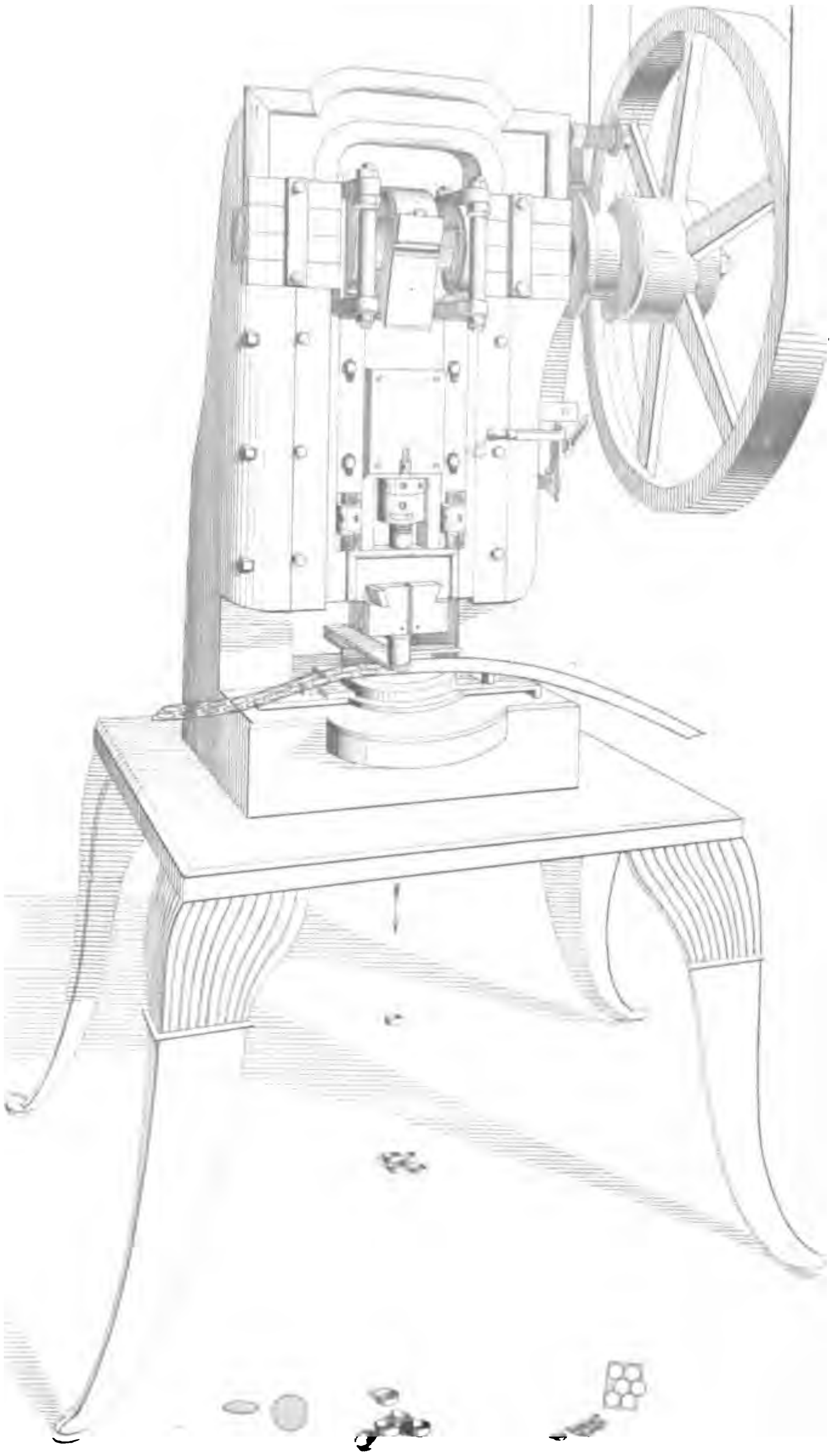
J. P. FARLEY,

CAPTAIN OF ORDNANCE

UNDER DIRECTION OF

BVT. LT. COL. T. J. TREADWELL

MAJOR OF ORDNANCE



DOUBLE ACTION PRESS.

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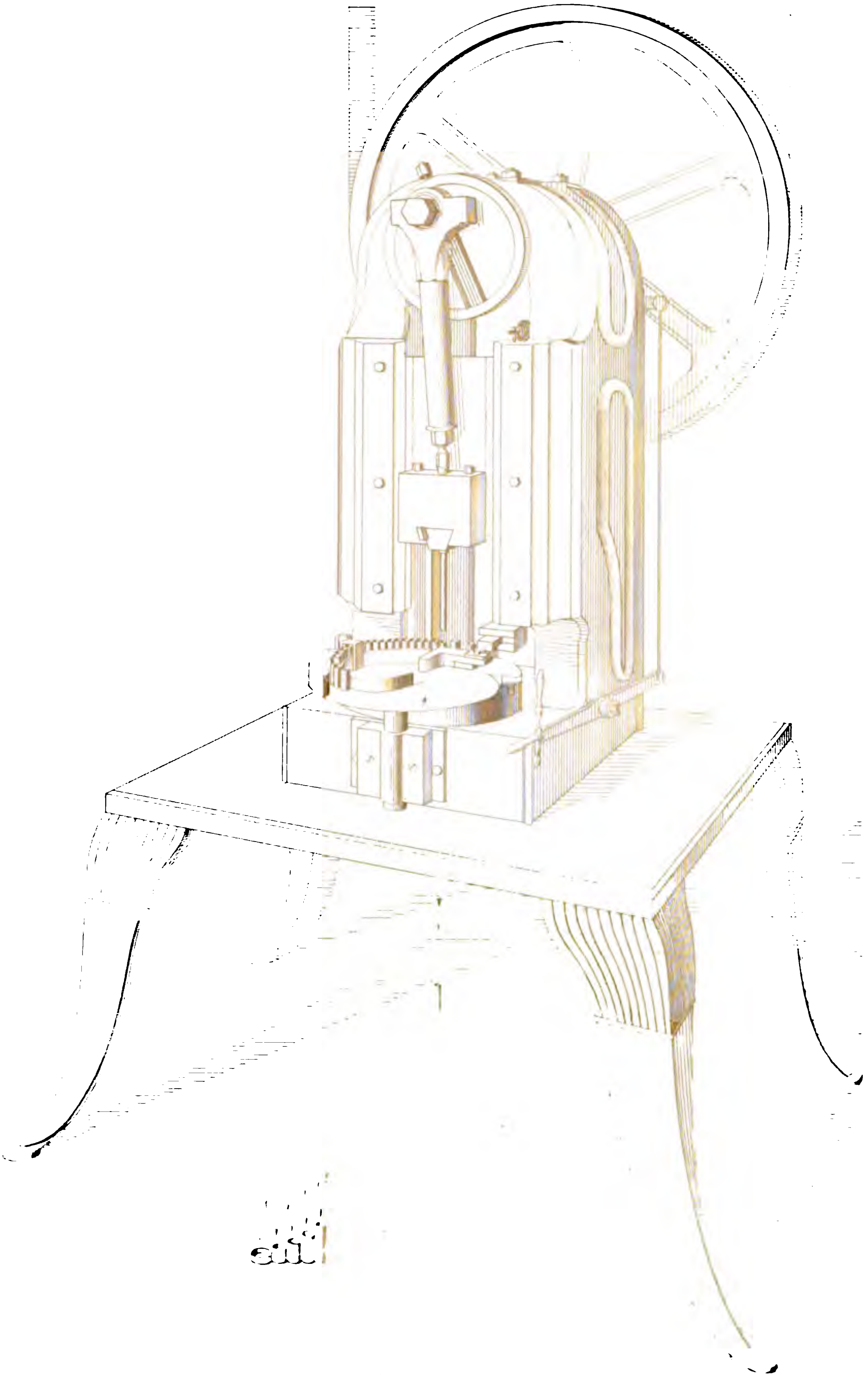
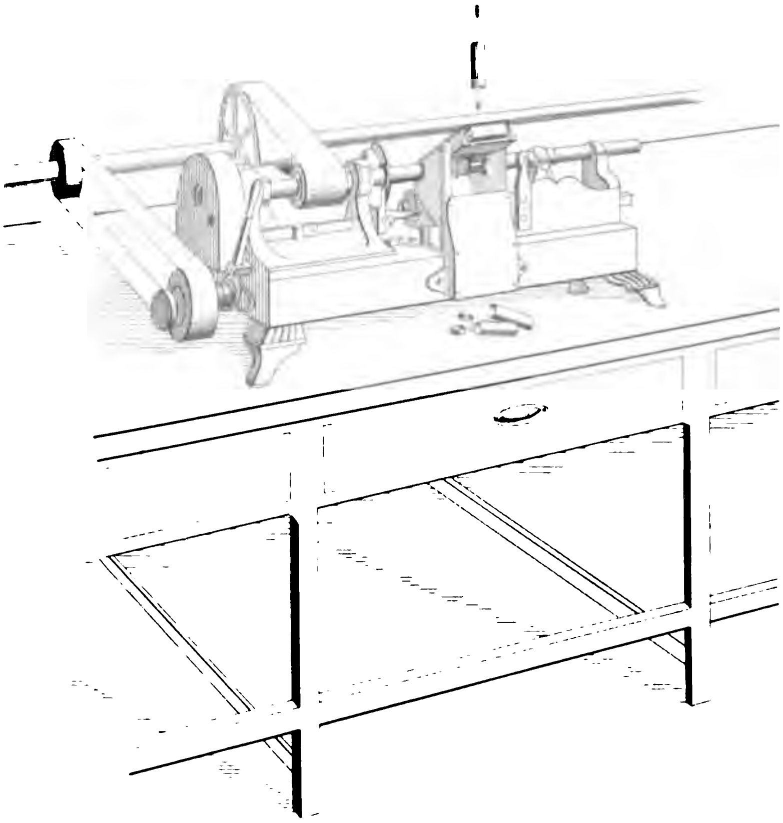


SINGLE ACTION PRESS



TRIMMING MACHINE.
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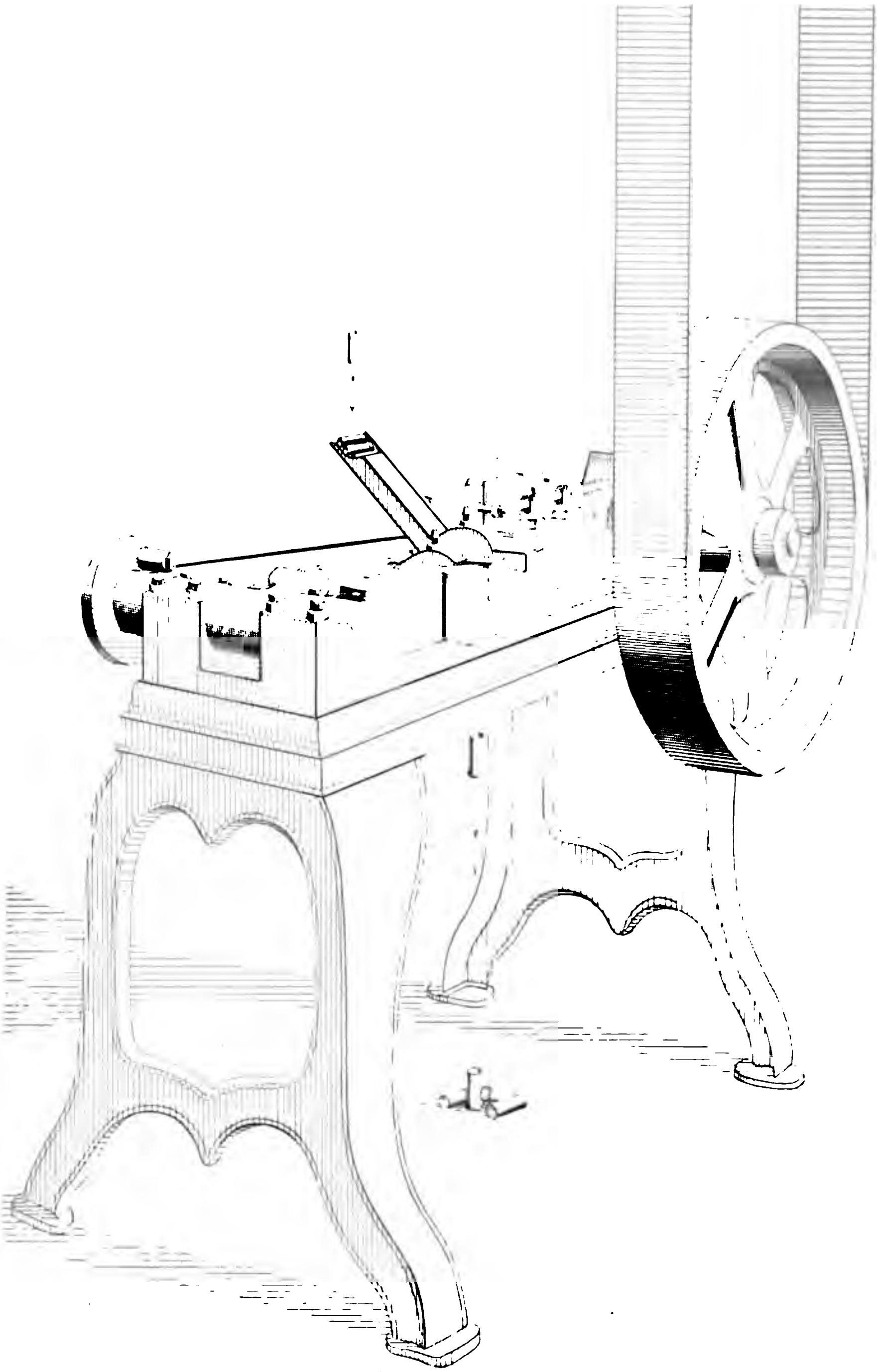

HEADING MACHINE.

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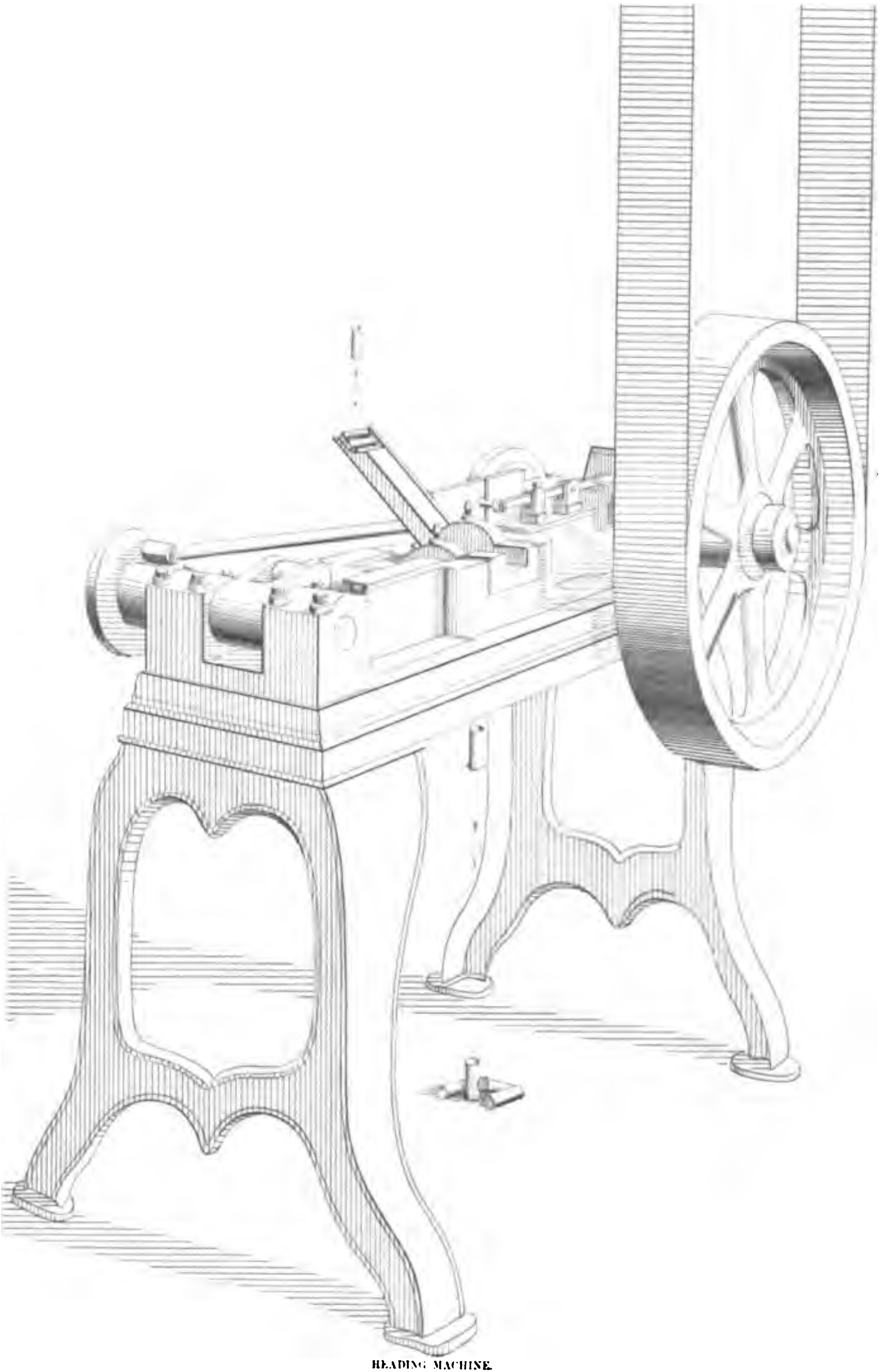

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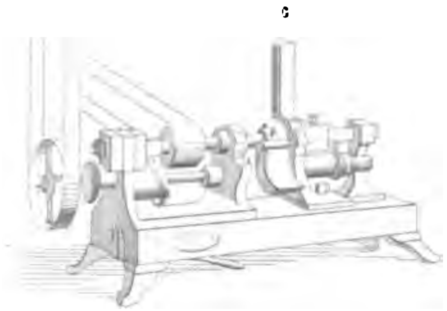

CUP TRIMMING MACHINE

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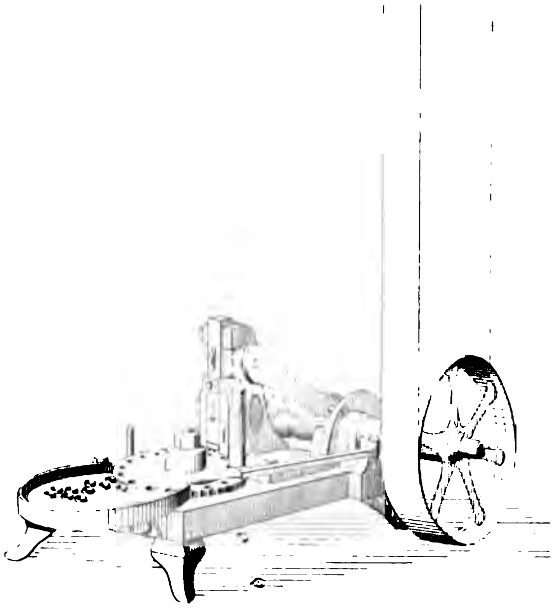
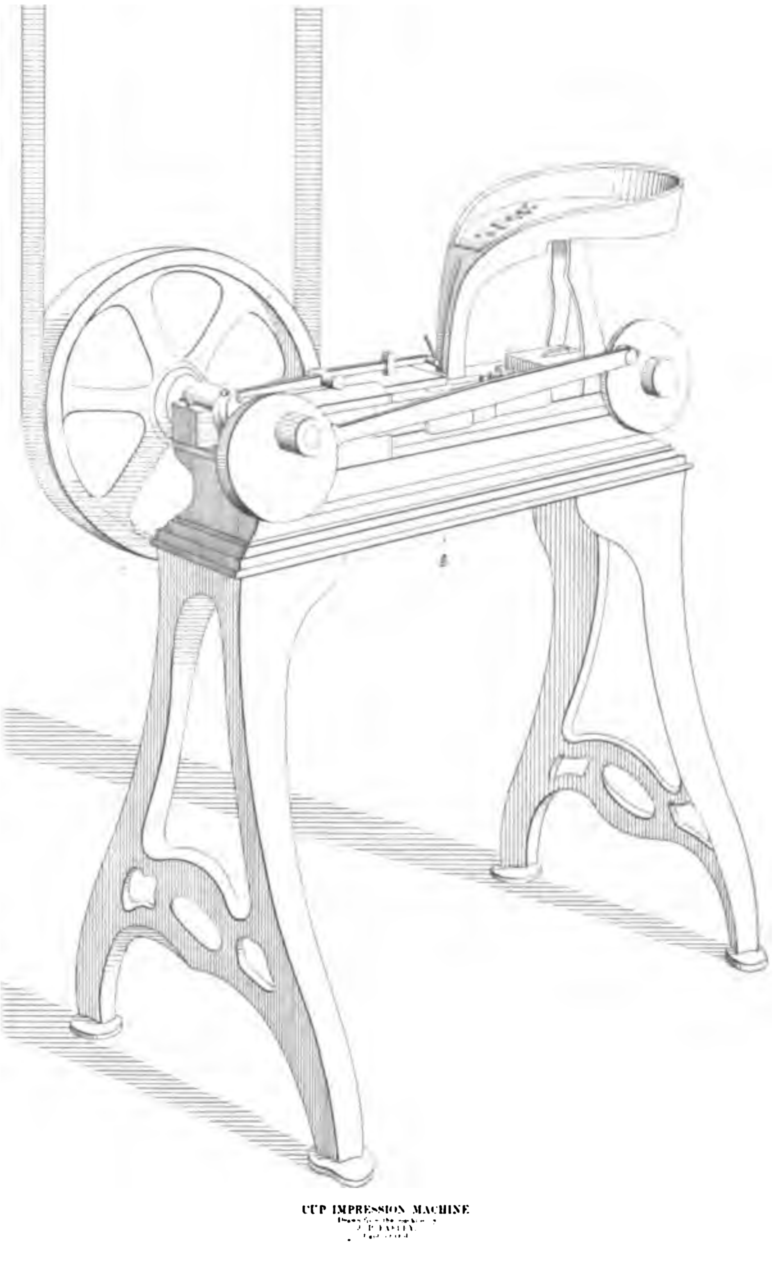


CUP VENTING MACHINE.
Drawn from the machine by
J. P. FARLEY
Capt. of Ord.



CUP IMPRESSION MACHINE
Drawn from the machine by
J. P. BAILEY.
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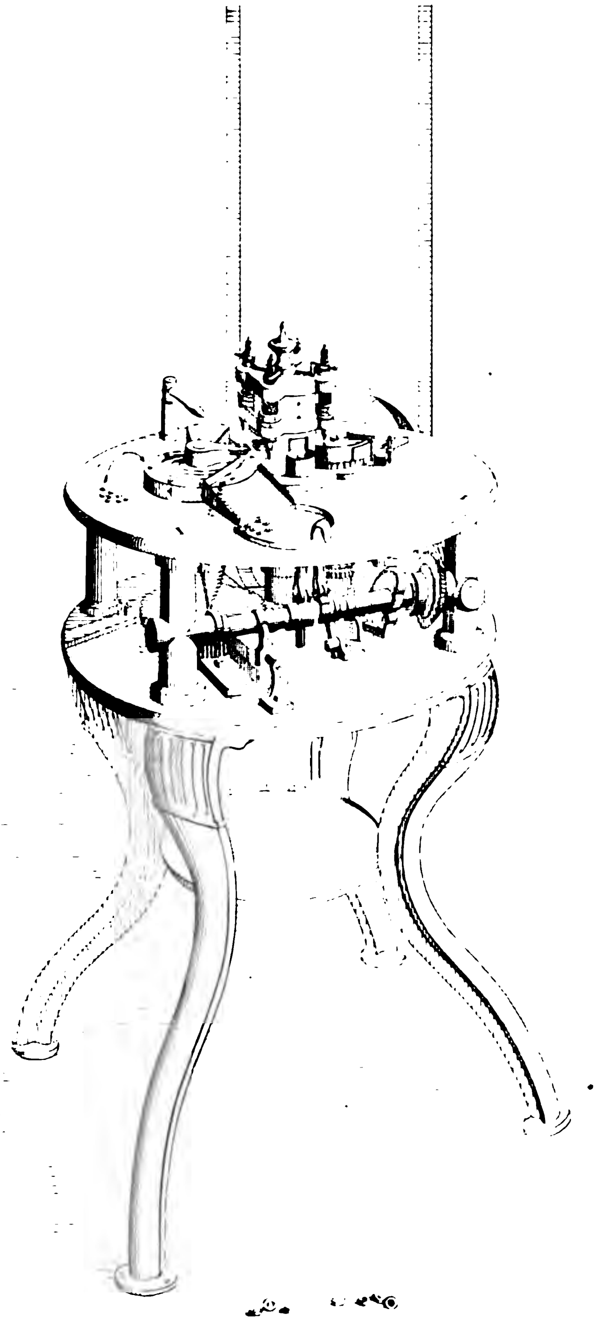
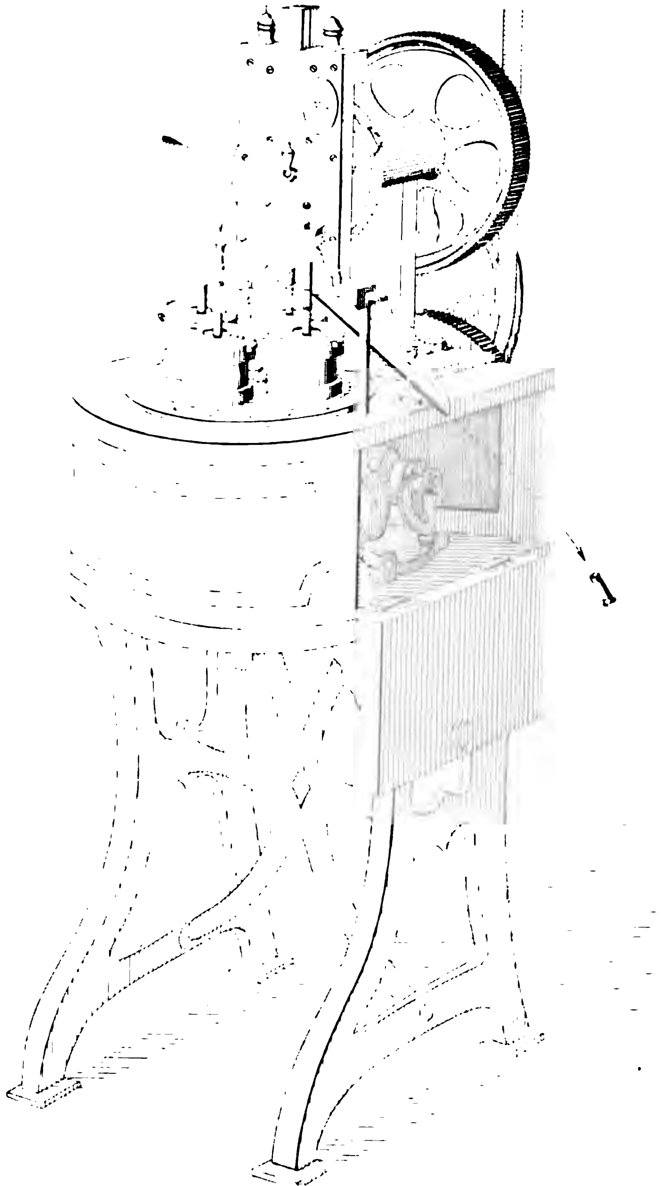


PRIMING MACHINE



TAPERING MACHINE

Drawn [illegible] by

J. P. [illegible]

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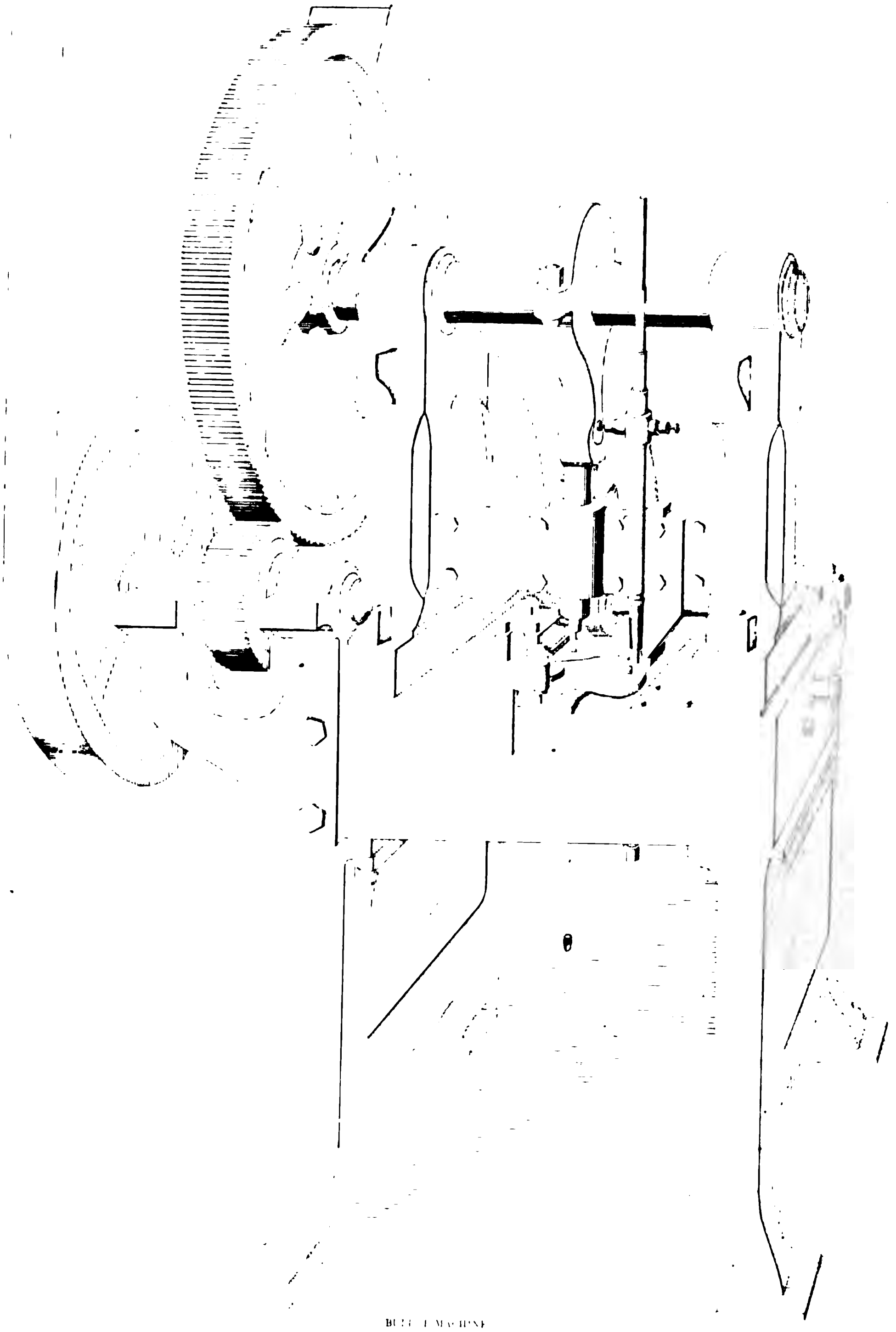
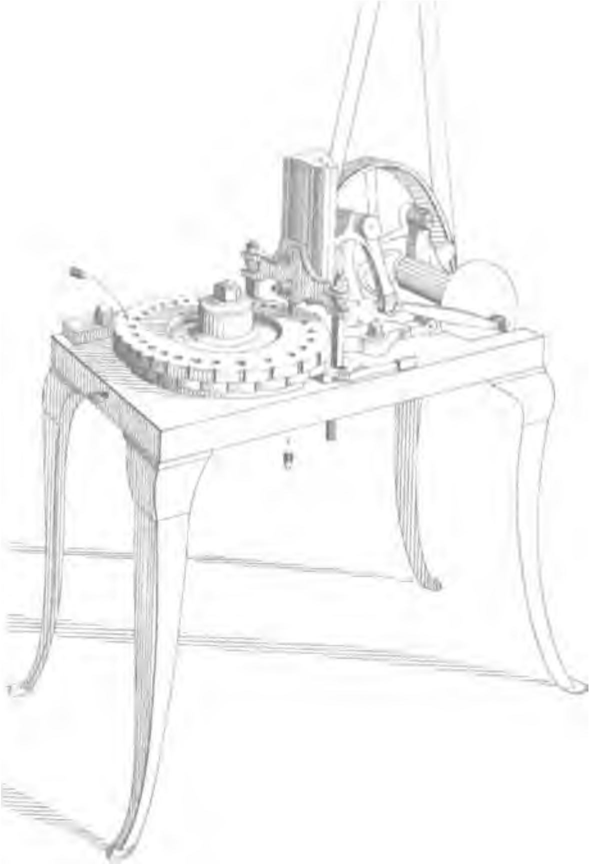
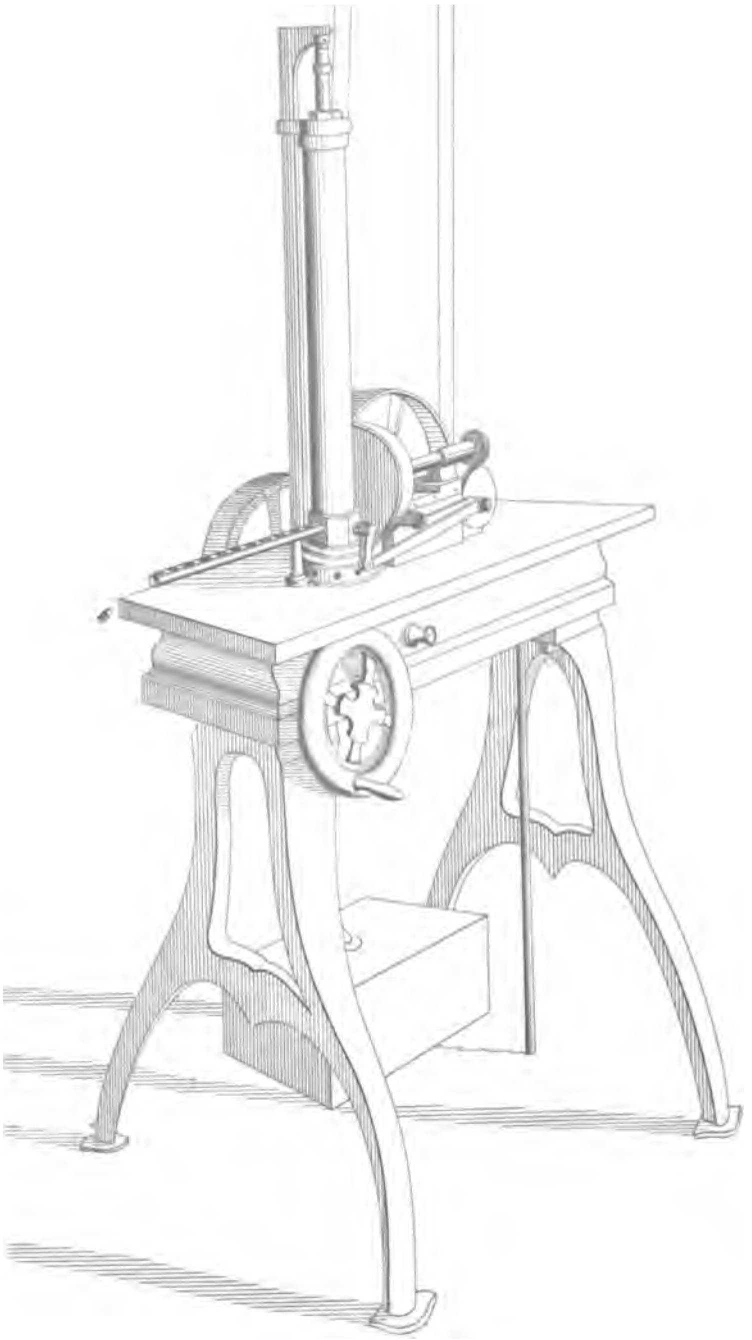


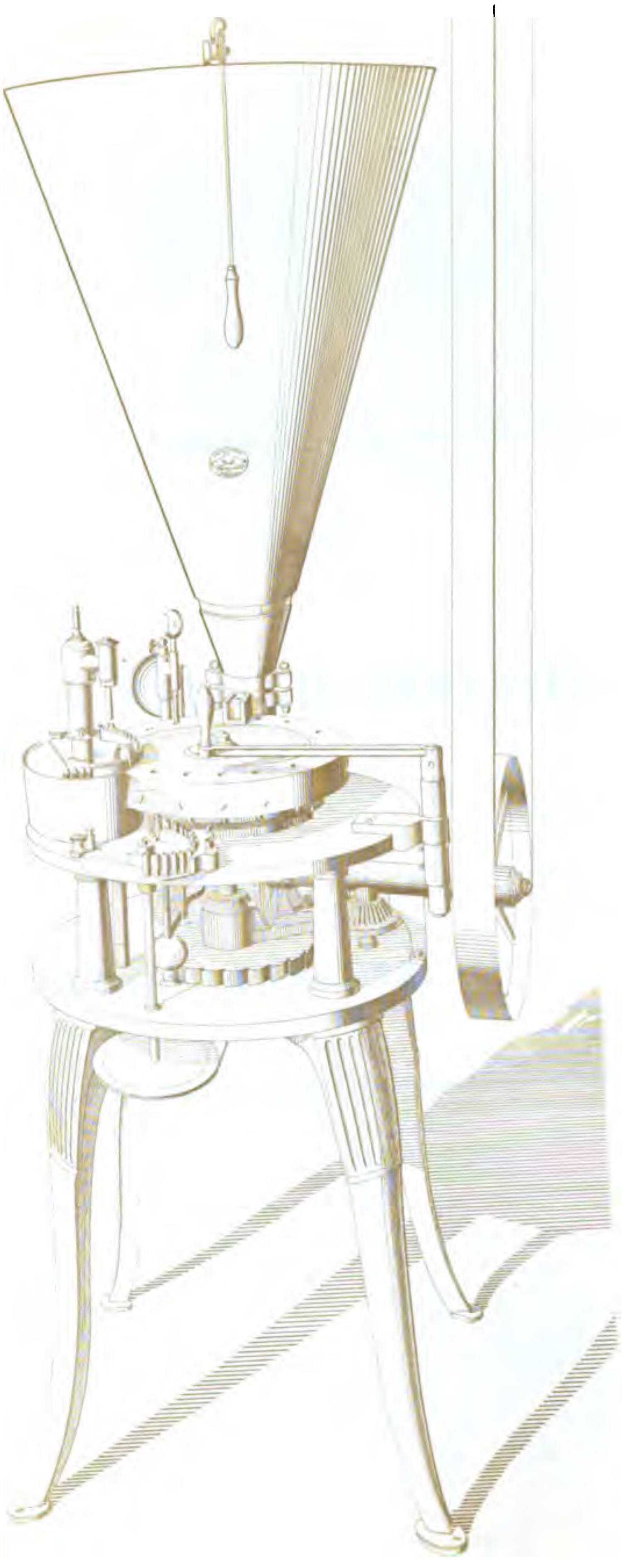
BULLET MACHINE



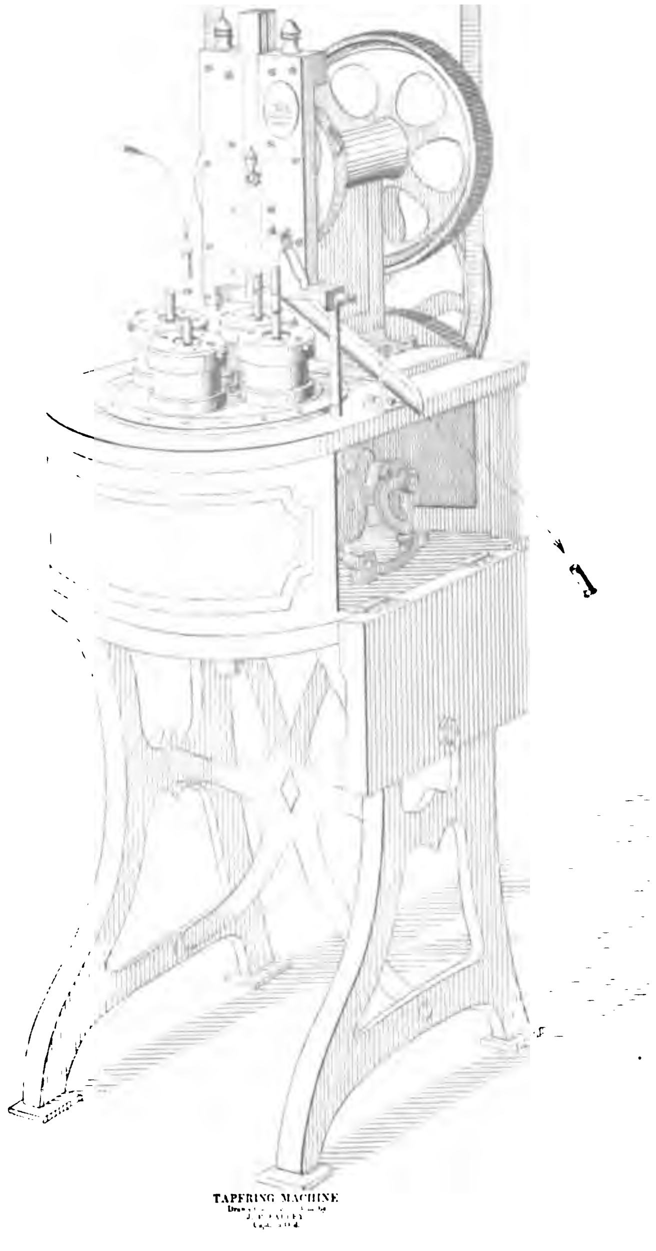
BULLET TRIMMING MACHINE.



LUBRICATING MACHINE.
Drawn from the machine by
J. P. FARLEY
Capt. of Ord.



LOADING MACHINE



TAPERING MACHINE

Drawn [illegible] by

J. F. [illegible]

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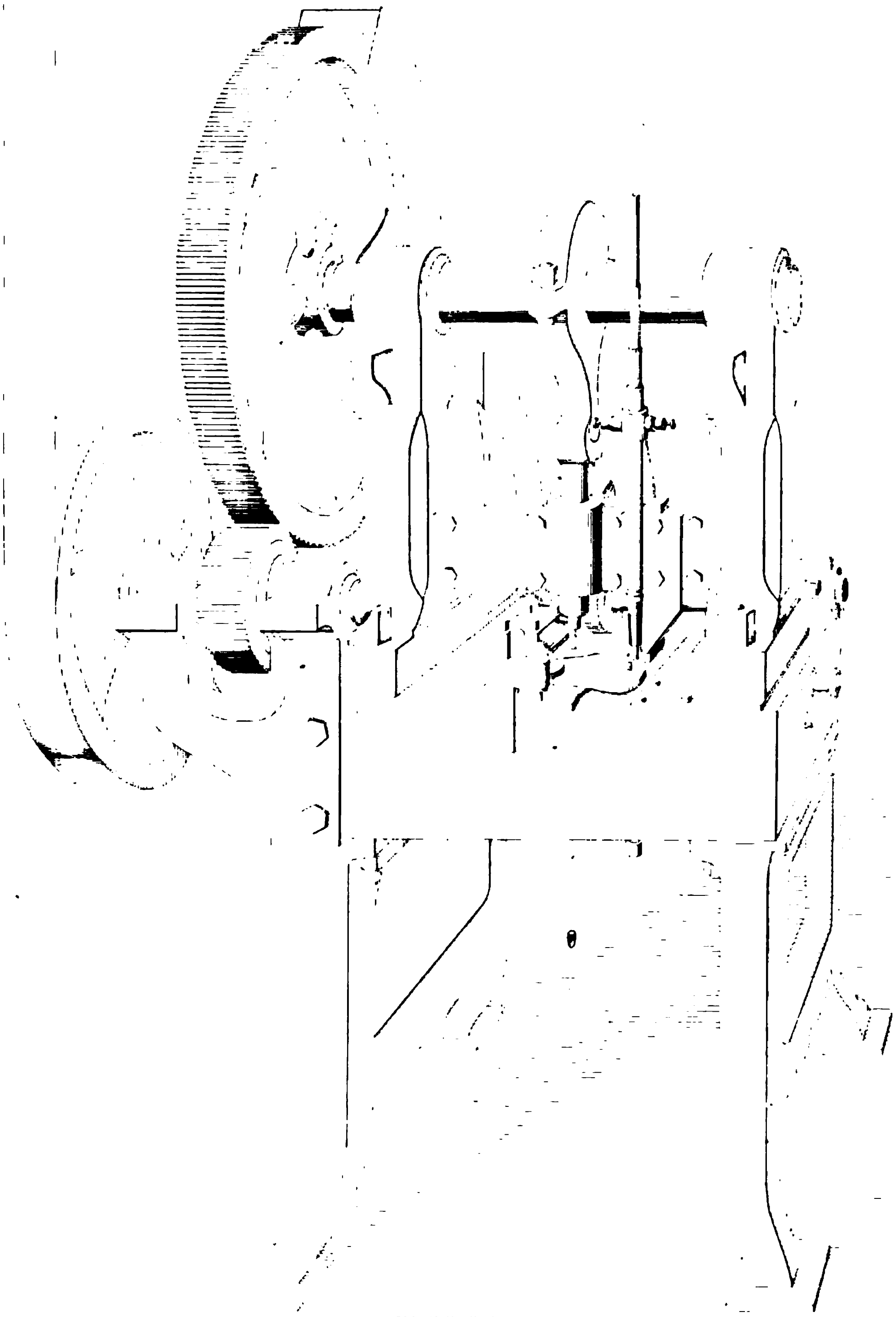
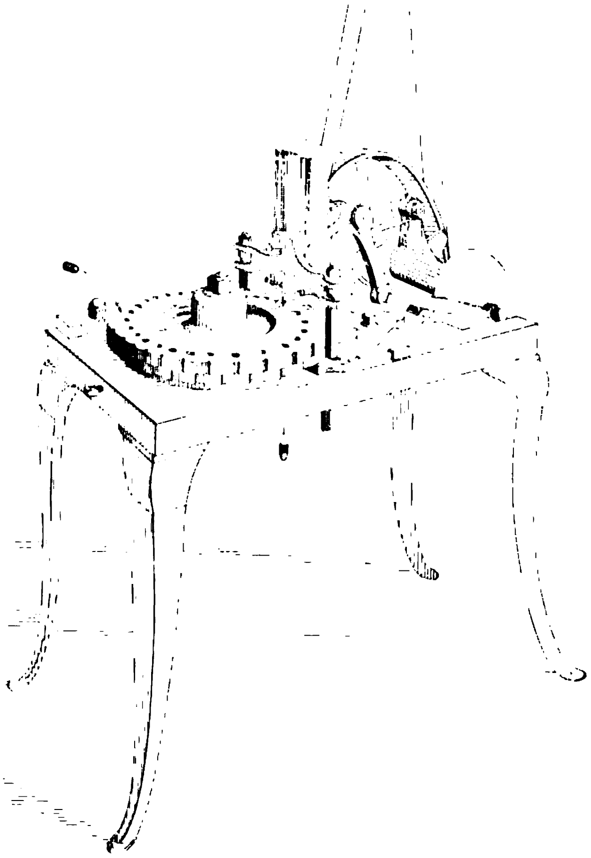


BULLET MACHINE



BULLET TRIMMING MACHINE

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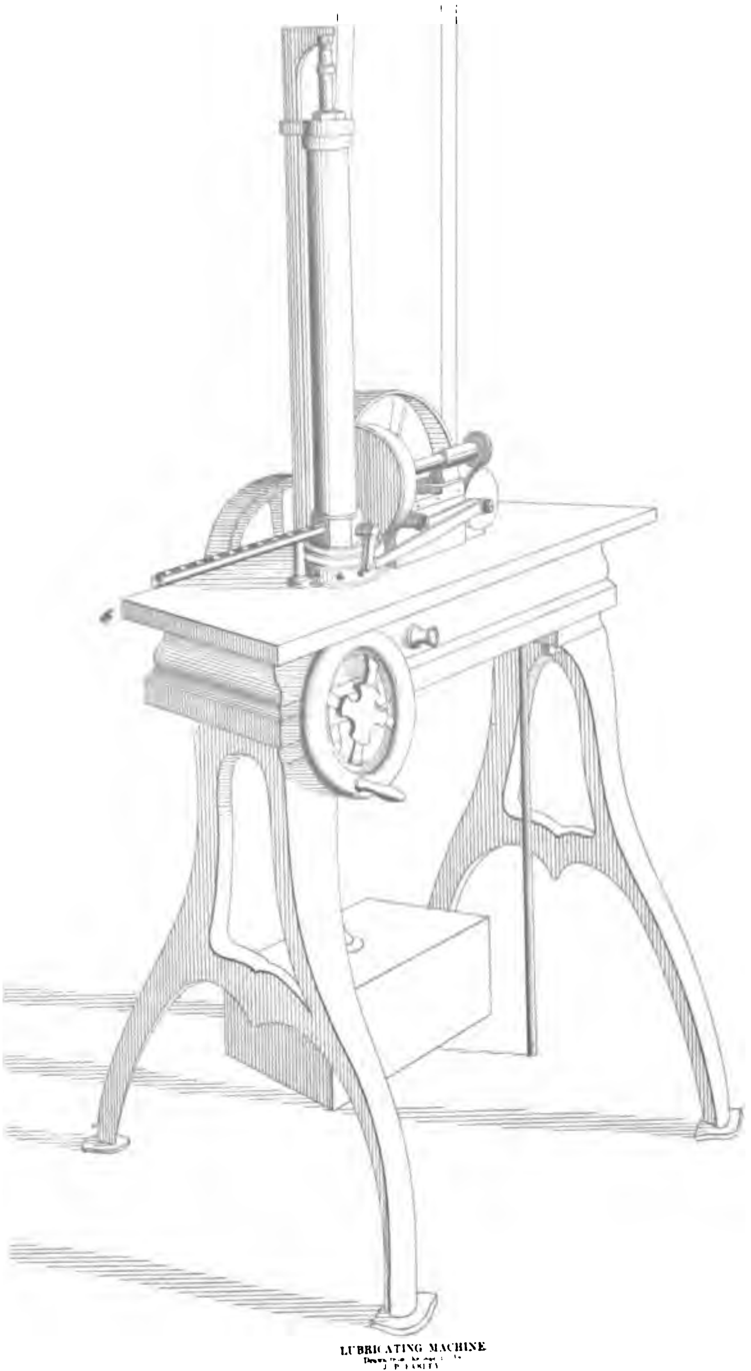

LUBRICATING MACHINE
Drawn from [illegible]
J. P. EASLEY
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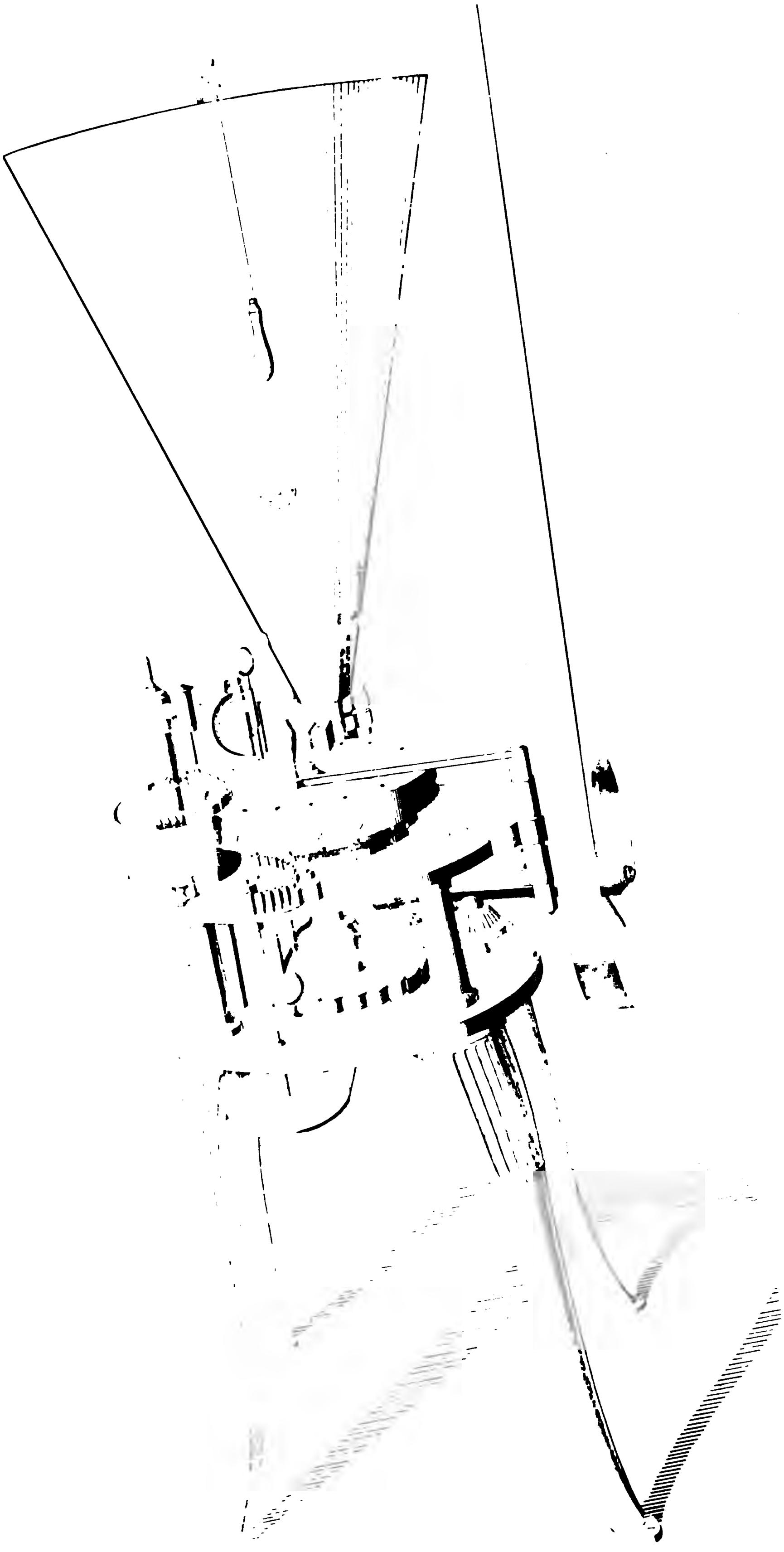

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EXPERIMENTS WITH

SMALL ARMS AND METALLIC AMMUNITION

AT

FRANKFORD ARSENAL.

REPORT OF EXPERIMENTS

BY

BREVET CAPTAIN WILLIAM PRINCE, ORDNANCE DEPARTMENT.

SMALL ARM AMMUNITION.

The necessity for detecting the slightest falling off in the quality of any of the constituents of our small arm ammunition, as well as preserving the full efficiency of the completed product, renders necessary an unremitted succession of tests and trials with the most approved appliances of modern science, adapted to the various special requirements of the service, and improved by the accumulated experience of constant use. The same facilities are also largely employed in experiments for improving our present ammunition in its several features and general efficiency, as well as in determining such special questions in small arm practice as may be directed by proper authority.

The apparatus and appliances used in these tests and experiments may be divided into two classes:

I. Those intended for testing in detail, as *raw material*, the various elements of the ammunition; and—

II. Those used for testing the *finished cartridge* in its various desiderata, and for settling such questions of detail as can only be properly determined by the performance of the completed ammunition.

Under the FIRST CLASS may be mentioned:—

1st. The Testing Machine for tensile strength, etc., which is used for determining the strength of the sheet metals employed, their resistance to detrusive force in pressing, drawing, etc., as well as the forms of least resistance for dies and other forming tools. This machine is arranged to measure the force exerted by a hydraulic press up to 50,000 pounds, with an approximation of $\frac{1}{10,000}$, and can be applied to the measurement of compressive, tensile, transverse, torsional, or detrusive strains as may be desired. By this machine the standard of excellence in the sheet metals employed in the fabrication of cartridge cases can always be verified. One of its principal uses, however, is in measuring the force necessary to reproduce the indentations of the Rodman pressure plug.

2d. Appliances for testing such essential qualities of the gunpowder as can only be determined before its manufacture into cartridges. These consist of the apparatus and re-agents for testing the proportions and purity of the ingredients of the powder, the gauges for size of grain, percentage of dust, etc.; and apparatus for obtaining the gravimetric density of powder at various degrees of compression, as well as its absolute density by the mercurial process.

3d. Drop machine for testing the sensitiveness of fulminate. The fulminate, being manufactured at the Arsenal, requires only to be tested in the matter of grit and hardness of the ground glass which is incorporated with it, and on which its sensitiveness largely depends.

4th. Apparatus for testing materials used in lubrication.

The above constitute some of the principal arrangements for the trials of raw materials; although many of their most important qualities can only be properly determined by trials of the finished ammunition.

Under the SECOND CLASS may be mentioned:—

All those apparatus and appliances for determining the *initial velocity* and *pressure generated by the powder*; the *strength and proper shape of the case*; the *model and consequent flight of the bullet*; the *efficiency of the lubrication*, and consequent cleanliness and sustained performance of the ammunition; and the *uniform ignition of the fulminate.* How far any or all of these qualities are affected by time, temperature, moisture, rough usage, &c., are questions of considerable importance in the examination, study, and trial of both raw materials and the completed cartridge.

INITIAL VELOCITIES.

For determining Initial Velocities, the most refined and elegant applications of electro-magnetism and induction to ballistics are utilized, in the shape of the Benton and the Vignotti Electro-Ballistic Pendulums, and the Schultz Chronoscope, as described in Colonel Benét's work on Instruments for Minute Chronography. While the complete explanations of that work render any further reference to the principles and general construction of these machines superfluous, it may be well here to note some of the improvements which experience has suggested in their details and accessories, with a view to eliminate minute sources of error, and render their use at all times simple and reliable.

The Vignotti Pendulum is started by means independent of either target, so that both ruptures are recorded during the rapid movement of the pendulum in the lower portion of its arc. By encasing the marking point in glass, the liability of the spark to

occasionally strike obliquely into the plate is removed. The circuit traversed by the current is the same in both targets, securing equal resistance and consequent equal intensities of spark at both ruptures.

The advantage of this latter arrangement is most marked in the use of the Schultz Chronoscope, to which it is now applied, together with several other modifications suggested by experience. The system of targets described by the inventor was found open to many objections. The repair of these harp-like targets after every shot becomes extremely tedious where a protracted series of experiments are in progress, and the ends of the ruptured wires when swinging loosely will make accidental contacts and produce sparks which vitiate and confuse the record. The rupture of these wires too, undoubtedly consumes some appreciable portion of the *vis viva* of a small projectile when the targets are numerous, and the bullet sometimes experiences singular deflections from the wires, which result in broken target frames, or at least, imperfect records. The current traverses a longer circuit with each successively ruptured target, and the spark experiences corresponding variations of intensity and indication. Perhaps, however, the most prominent and serious objection to these targets is the general delicacy of their mechanism and adjustments, in view of their exposed position and liability to derangement and accident. The cost of construction and repairs increases greatly with their increased distance, number, and size, as every wire must have its lever and spring, and the derangement of one spring is the derangement of all.

Most of these objectionable features are removed or greatly diminished by the following arrangement: The primary current wire is carried in one unbroken reach to the most distant target it is proposed to use, and returns through all the targets. These targets are formed of paper stretched on light frames hanging behind framed supports, against which they are pressed by light springs. As the projectile makes its way through the successive targets it pushes each one away from its support for an instant, breaking, by that act, the circuit of the returning current which has been suitably arranged to be so broken, and to be instantly restored by the return of the suspended target to contact with its support. The current is thus identically the same for every target, the circuit being opened and closed as by the key of an operator at each. No repairing of wires and readjusting of springs and levers is necessary after each shot; and so far from an accident occasioning cost and delay, the cost is nominal, and a few reserve frames of the various sizes can be kept on hand for casualties. It is believed that the *single loop* arrangement of circuit possesses advantages for all electro-ballistic machines whose principle does not preclude its use.

The only other modification of the original chronoscope here worthy of remark is the removal of the "interrupter" from the framed stand of the instrument to an independent pier exclusively devoted to it. This change was necessitated by the fact that vibrations were generated in the shelf on which the "interrupter" stood, which occasioned "interferences" with the vibrations of the interrupter itself.

PRESSURES.

The determination of pressures is effected through the medium of the Rodman Pressure Plug, which it is unnecessary to describe here, further than as regards the modifications incidental to its application to metallic ammunition.

To give the gas of explosion access to the piston of the apparatus, a circular opening of proper dimensions must of course be made in some portion of the metallic casing of the cartridge; and this opening was at first made concentrically in the bottom of the case. With ammunition of this kind the pressure piston was in the prolongation of the bore in rear of the barrel, and was contained in a solid housing which replaced the ordinary breech mechanism of the gun. By this arrangement the gun could only be loaded by unscrewing the barrel from its housing, inserting the cartridge, and then screwing the barrel up again to a tight joint.

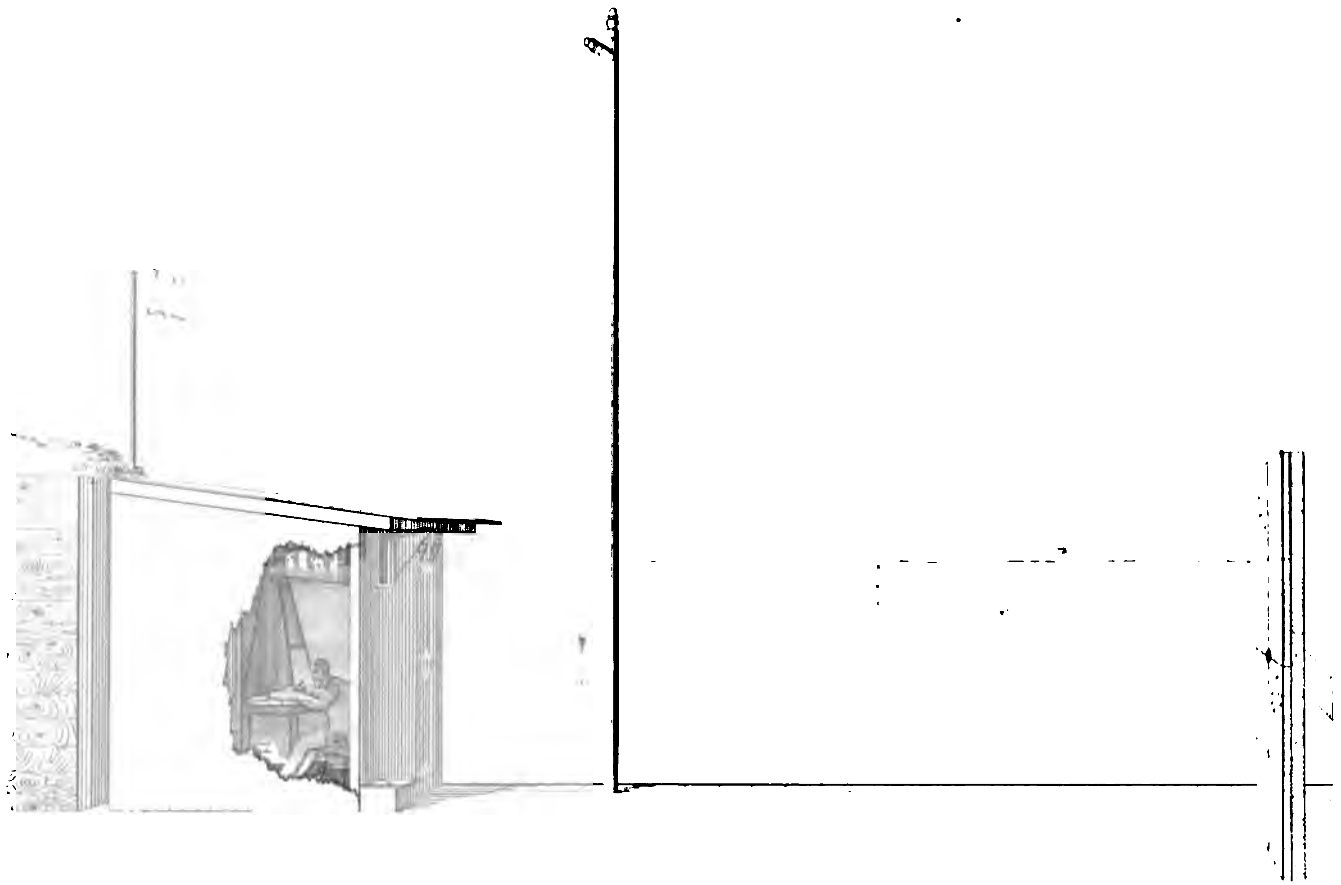
This process was found extremely troublesome when using a fixed rest, as is done in taking velocities and pressures from the same shots. The most serious objection to it, however, was that it involved the necessity of "rim priming," precluding entirely any trials with the accepted form of ignition in "center-fire" cartridges. In the pressure trials at this Arsenal, the ordinary housing of the breech mechanism of the gun is tapped on its upper surface, in front of the hinge, to receive the screw of the pressure piston gallows, the tap bore being continued to the interior of the barrel. Each cartridge case is furnished with a circular opening in its side, which, when loaded, comes opposite to the opening of the pressure apparatus in the upper surface of the chamber. By slightly thinning the edges of this side opening, by burnishing inside, it forms an effective gas check, and the whole arrangement gives very satisfactory results, uniform for the same ammunition, and with little or no escape of gas. The opening in the side of the cartridge is of course closed temporarily with paper to prevent escape of powder in handling. The gun can be loaded as rapidly and easily as the ordinary arm.

TARGET GROUND AND FIXTURES.

While initial velocities and pressures are determined separately or conjointly by their special apparatus, nearly all other qualities of the ammunition are ascertained directly or incidentally from target practice at various ranges with suitable rests and other appliances.

The target ground and fixtures at this Arsenal possessing some peculiar features, a brief description of their arrangement and use is appended.

The GROUND set apart for this purpose, near the northeast boundary of the Arsenal grounds, is five hundred yards in length, terminating on the Delaware river. No longer line could be secured without interfering with permanent improvements.



TARGET AND CAMERA, FRANKFORD ARSENAL

The STRUCTURES pertaining to the ground consist of one *Firing House*, two *Target Houses* with their screens, and two cast-iron *Targets* at distances of three hundred and five hundred yards from the firing house, and of dimensions 12′ × 12′ and 15′ × 15′ respectively.

The Firing House is provided with an improved *Fixed Rest* on brick pier, together with arrangements for firing from the shoulder and rest, recoil apparatus, etc. It is also supplied with armorers' bench and tools, desk, scales, clinometer, levels, telescope, etc., together with the usual instruments for determining the state of the atmosphere.

The Target Houses with their screens are situated one in front of each target, at a distance from it of fifty feet and to the left of the plane of fire. They face their respective targets, and each has arrangements for a camera lens, which, by means of a mirror, throws an image of the target, reduced to one-twelfth, on the surface of the table, at which sits the target recorder. Lithographed target diagrams to scale, one of which, duly dated and numbered, is placed upon the table at the commencement of each series of twenty shots, enable the recorder to mark the position of each shot as it strikes, thus avoiding the delay and some degree of risk incident to the usual method of recording. These diagrams, moreover, duly signed and numbered, are filed as vouchers to their respective pages in the "Record Book of Experiments." A telegraph key and sounder at the side of the recorder place him in communication with the firing party.

The Targets are of the usual construction, the angle of depression of their centers being only seven feet for the five hundred yards, and twenty-one feet for the three hundred yard one, as viewed from the firing house.

These arrangements have been in operation for some ten months, and the work of recording accomplished by their means is done accurately, safely, and with a rapidity limited only by outside considerations. It is, however, strongly recommended that, at some future time, the present cheap experimental device for a camera be replaced by an achromatic lens and prism. The illumination and definition of the picture would be thus greatly increased, and the only difficulty heretofore experienced (on dark days) would be entirely removed. When this is done the prism should be of flint glass and itself constitute the correcting concave element of the combination, which should be achromatic for conjugate foci of 54 feet and 54 inches, and aplanatic for an angle of 23° with an effective aperture of at least 2½ inches.

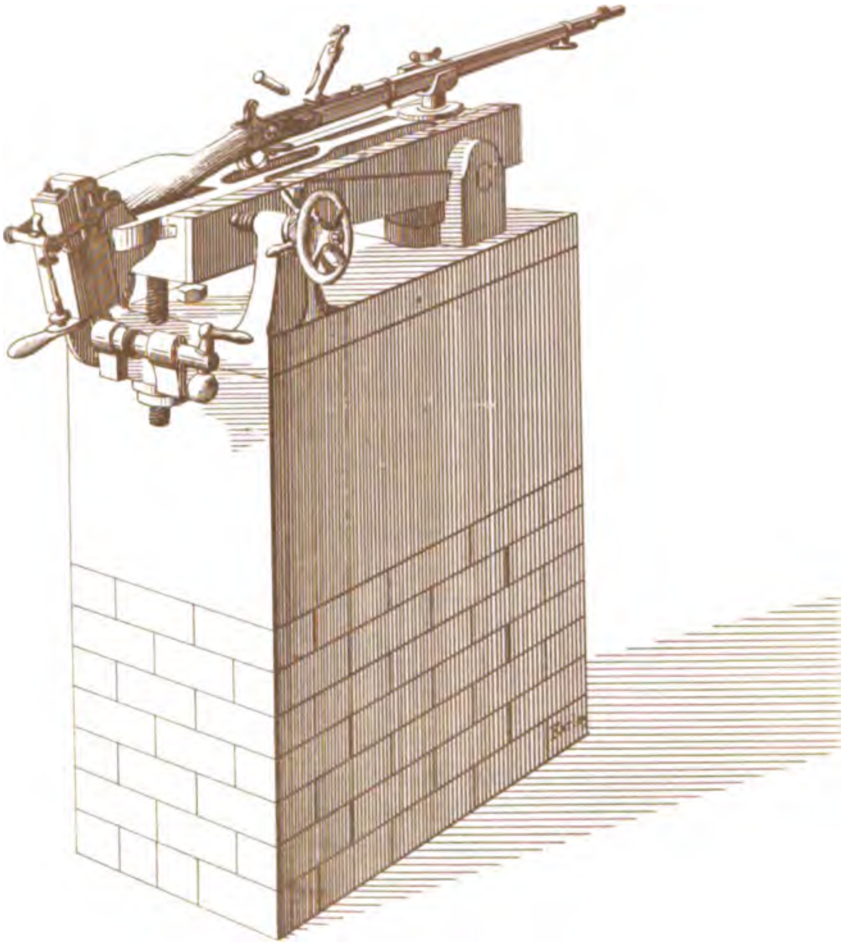
The desiderata of a Fixed Rest are strength, solidity, capacity of adaptation to various models of small arms, facility in securing the arm firmly in position, without undue strain upon any of its parts, easy but steady recoil and capacity for nice pointing and adjustment. The principal fixed rest at this Arsenal is an attempt to embody these qualifications in the following manner:

The support consists of a heavy freestone block resting upon a brick pier, and carrying the cast-iron bed plate of the rest as a cap covering its top and a portion of its sides. In this bed plate is sunk the pintle which carries the trunnions upon which the *chassis as well as the top-carriage* move in a vertical plane. The chassis controls the recoiling top-carriage by accurately planed and scraped guides, whose surfaces have bearings upon its sides for a length of thirty-two inches; and, owing to the center of vertical motion being beneath, the recoil is always parallel to the axis of the piece at every elevation. The top-carriage contains the arrangements for directly supporting the piece, and these are so constructed as to dispense with direct screw pressure upon any portion of it. The points of support, in addition to the butt-stop, are as usual two, one near the butt and the other at about thirty inches in front; at neither point, however, is any side screw clamp allowed to act directly upon the arm. At the rear, the stock rests in a V while an inverted Λ descends upon its upper surface and secures it laterally as well as vertically by the pressure of a spring whose tension can be increased at pleasure. Meanwhile the thrust-block in rear of the butt plate—a solid brass segment moving vertically in a corresponding segmental bed—adjusts itself to the points of contact with the butt plate. The front support is also a V into which the barrel is pressed by the polished surface of a flat leaf spring above, which latter can, like the spring at the rear support, have its tension increased up to the limits of the strength of the rest.

The advantages of this arrangement are the perfectly *symmetrical* character of the support afforded to the piece; the coincidence of the plane of sight with the plane of fire secured, without adjustment, as a mere consequence of the style of support; the absence of all distortion or buckling of the piece by local strains, or restraint of its longitudinal reaction, and the fact that the arm can be readily secured or released from the rest, as, when the tension of the restraining springs is once adjusted, the piece can be removed or returned and securely clamped, almost with a mere click, and will be found sighted upon precisely the point last aimed at. All bearing surfaces, journals, elevating and traversing screws, &c., about the machine are massive, far beyond the requirements of mere strength, and sufficiently highly finished to give great smoothness and steadiness to all adjustments, as is evidenced by the fact that alterations to the tenth of a minute can be made and read with ease and certainty in any direction by two independent means, the vernier and the micrometer screws. In adjusting the lines for the sights of small arms, both means are always used, and a discrepancy of more than 0′.1 between them would demand a repetition of the trial.

With the fixed rest and targets as described, all questions regarding accuracy and uniformity of flight of projectiles, can be determined by the usual method of co-ordinates and centers of impact.

The subject of investigation may be the performance of a known arm with a new ammunition, or a known ammunition with a modified arm. A new arm with its own special ammunition may, too, be under trial as a whole system, but, in any case, the average trajectory, and the degree of closeness and uniformity with which the practice adheres to that average trajectory, can be determined.



FIXED REST, FRANKFORD ARSENAL.

REPORT OF EXPERIMENTS

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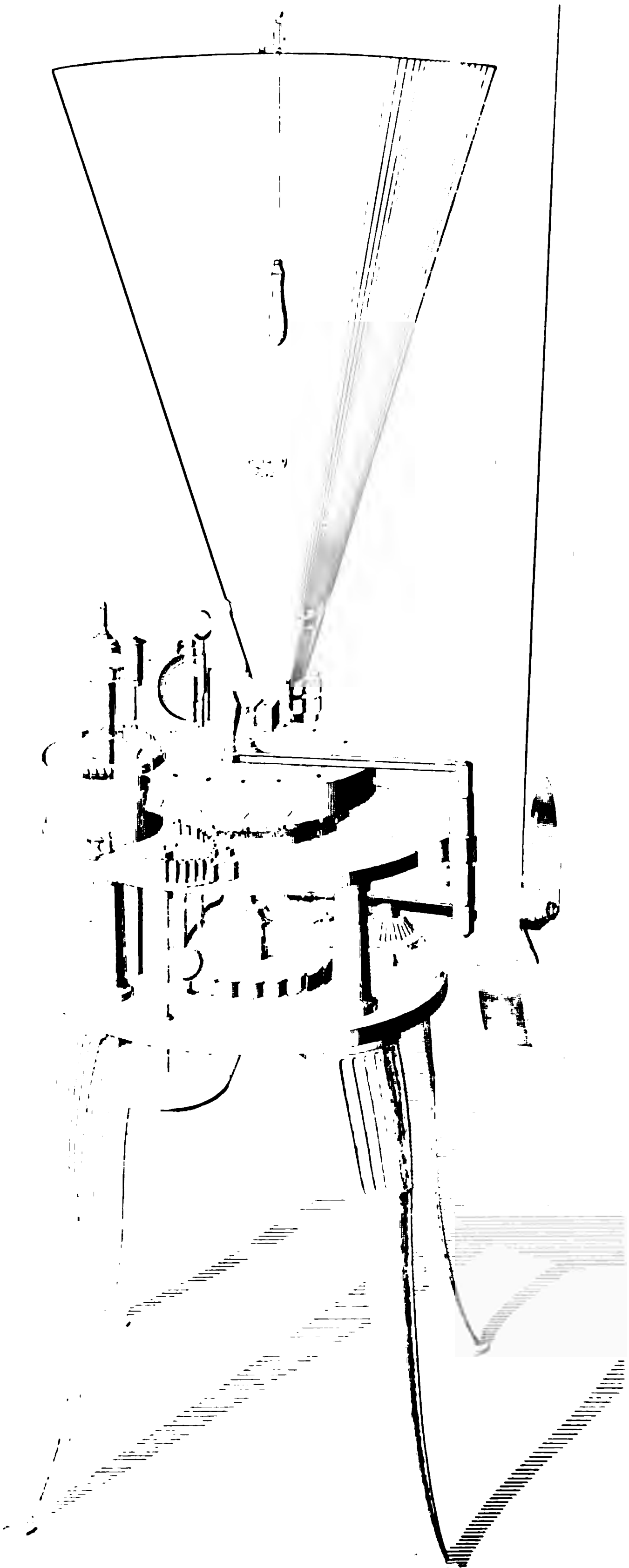

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EXPERIMENTS WITH

SMALL ARMS AND METALLIC AMMUNITION

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It is apparently intended to combine the expanding and slugging principles in taking the grooves—the swell in front slugging to a bearing, while the thin funnel-shaped cup of metal included between the base-cavity and the cannelure expands to secure a bearing-ring at the rear.

The bullets were of pure lead, of the same weight as the service bullet; and the ammunition was made up, in all respects, similarly to the usual center-fire metallic cartridge for the Springfield breech-loading rifle-musket, caliber .50. The lubricant was applied in the wide cannelure described.

Targets were fired at 300 and 500 yards; and for penetration, initial velocity, and recoil, a series of shots were fired with the usual appliances. The effect of fouling was also determined by firing four targets without cleaning. The results as compared with the service ammunition are here tabulated:

FOUR TARGETS AT 300 YARDS WITHOUT CLEANING.

	ROBERTS'S.	SERVICE.
First 20 shots in the hundred, mean absolute deviation	1'.021	0'.520
Last 20 shots in the hundred, mean absolute deviation	1'.644	1'.453
Corrected angle of sight	54' 57"	48' 5"
Fouling from 108 shots ... grains	52	32
ONE TARGET AT 500 YARDS.		
Mean absolute deviation	1'.472	1'.256
Corrected angle of sight	1° 36' 37"	1° 28' 26"
Fouling from 27 shots ... grains	6	6.2
Penetration at 50 feet, inch pine boards	10.6	12.1
Recoil ... pounds	95	89.65
Initial velocity, (targets 100 feet) ... feet	1209.8	1235.5

Targets at 300 yards, 12' × 12'. Targets at 500 yards, 15' × 15'. Wind—light air from left of front. Thermometer 41° to 45° Fahrenheit. Air 75 per cent. saturated. Barometer 30.50" to 30.48".

The recoils are both less than the absolute recoil; the apparatus increasing the weight of the gun by 6¼ lbs., but *relatively* they are reliable.

The only other peculiarity that was observed was, that the extremely blunt head of the bullet detracts somewhat from the facility of loading by occasionally embarrassing the operation of inserting the point of the cartridge.

Other Bullets.

THE CONICAL CONOIDAL.

A conoidal front upon a reduced conical frustrum. Two varieties—"short," 1" in length; "long," 1".1 in length.

SHORT CONICAL CONOIDAL BULLET.

Extract from Report of November 5, 1869.

* * 100 shots at 300 yards, without cleaning :

First 20 shots in the hundred, mean absolute deviation	0'.771
Last 20 shots in the hundred, mean absolute deviation	2'.853
Corrected angle of sight	50' 45"
Fouling from 108 shots	147 grs.

LONG CONICAL CONOIDAL BULLET.

Extract from Report of May 24, 1870.

* * 100 shots at 300 yards, without cleaning:

First 20 shots in the hundred, mean absolute deviation	0'.524
Last 20 shots in the hundred, mean absolute deviation	1'.887
Corrected angle of sight	36' 29"
Fouling from 124 shots	116.4 grs.

THE FEDERAL BULLET.

Imitation of the "Federal Bullet" of the Tyrolese riflemen.

Extract from Report of November 13, 1869.

* * 100 shots at 300 yards, without cleaning:

First 20 shots in the hundred, mean absolute deviation	0'.667
Last 20 shots in the hundred, mean absolute deviation	1'.008
Corrected angle of sight	49' 59"
Fouling from 108 shots	21.4 grs.

REDUCED SERVICE BULLET.

Diameter reduced .005", weight unchanged, metal being added at base.

Extract from Report of October 26, 1869.

* * 100 shots at 300 yards, without cleaning.

First 20 shots in the hundred, mean absolute deviation	0'.705
Last 20 shots in the hundred, mean absolute deviation	2'.781
Corrected angle of sight	55' 5"
Fouling from 108 shots	84.5 grs.

LUBRICANTS.

The features which it is desirable to embody in a lubricant for a metallic-case small arm cartridge are numerous and difficult of simultaneous attainment. Such a lubricant should, if possible, possess the following qualifications:

It should *lubricate* the surface of the bore effectively in warm or cold weather, in a damp or dry atmosphere. By effective lubrication is meant the prevention of all leading or accumulation of hard dry "powder fouling," either of which stimulates the deposit of the other. It should have sufficient body and stability to reach the muzzle of the piece under the highest temperature it may attain, without burning, volatilizing, or forming acroleine. It should be sluggish in its reactions and not liable to facilitate galvanic action between the lead and copper. Its melting point should be sufficiently high to avoid fluidity or even extreme viscidity at the highest temperature to which the ammunition will ever be exposed in storage or transportation. Its consistence should be of a character

A statement of the weight of fouling, etc.—Continued.

LUBRICANTS.		FOULING. 100 SHOTS. GRAINS.	REMARKS.
Beeswax Graphite	8 parts. 3 "	209	Same remark as last.
Beeswax Soapstone	4 parts. 1 part.	26	Works rather better in both machines.
Beeswax Soapstone	8 parts. 3 "	58	Same remark as last.
Beeswax Soapstone	2 parts. 1 part.	57	Same remark.
Japan wax		10	Works fairly in machines.
Japan wax Graphite	8 parts. 1 part.	4.4	Works fairly in machines.
Paraffine		198	Works well in both machines.
Paraffine Soapstone	4 parts. 1 part.	167	Same remark.
Bayberry wax		12	Works well in both machines.
Bayberry wax Graphite	8 parts. 1 part.	27	Works perfectly in both machines, being in fact the lubricant for which they were constructed.

The following are the congealing points of some of the materials mentioned, as they actually occur commercially. The melting point is usually from 6 to 10 degrees Fahrenheit above the congealing point, but the congealing temperatures represent the relative fusibility of the materials with nearly equal correctness and are obtained with much greater ease and accuracy. By dipping the bulb of a sensitive thermometer in the melted material, then withdrawing it and watching for the first appearance of mistiness on its surface, the congealing point may be noted with the last degree of accuracy. The degrees are:

Beef tallow congeals at	87°	Fahrenheit.
Stearine of beef tallow congeals at	92°	"
Stearine of lard congeals at	83°	"
Palm butter congeals at	88°	"
Palm stearine congeals at	92°	"
Cocoa butter (melts at 80°) congeals at	66°	"
Cocoa stearine congeals at	80°	"
Beeswax congeals at	141°	"
Japan wax congeals at	101°	"
Spermaceti congeals at	107°	"
Paraffine, crude, congeals at	128°	"
Paraffine, refined, congeals at	108°	"
Bayberry wax congeals at	125°	"
Bayberry wax, soft, (adulterated,) congeals at	111°	"

A statement of the weight of fouling from 100 shots with several of these lubricants is appended:

LUBRICANTS.	FOULING. 100 SHOTS. GRAINS.	REMARKS.
Stearine of tallow	3.3	Too soft for lubricating machine.
Stearine of tallow . . . . 16 parts. Beeswax . . . . 4 " Graphite . . . . 3 "	20	Clogs lubricating and loading machine.
Stearine of tallow . . . . 16 parts. Beeswax . . . . 4 " Soapstone . . . . 3 "	7	(200 shots gave 9 grains.) Difficult to work in both machines.
Stearine of tallow . . . . 8 parts. Beeswax . . . . 4 " Soapstone . . . . 3 "	19	(200 shots gave 20 grains.) Works rather better in machines.
Stearine of tallow . . . . 1 part. Beeswax . . . . 1 " Soapstone . . . . 1 "	19	(200 shots gave 71 grains.) Works about like the last in the machines.
Stearine of tallow . . . . 2 parts. Beeswax . . . . 3 " Soapstone . . . . 4 "	80	Works very well in both machines.
Stearine of lard	13	Can't be worked in lubricating machine; too soft.
Stearine of lard . . . . 4 parts. Soapstone . . . . 1 part.	7	Same remark as above.
Stearine of lard . . . . 2 parts. Soapstone . . . . 1 part.	4	Same remark.
Palm stearine	22	Worked only tolerably in lubricating machine.
Palm butter . . . . 1 part. Beeswax . . . . 1 " Soapstone . . . . 1 "	97	Works badly in both machines.
Cocoa stearine	3.7	Could not be worked in lubricating machine.
Cocoa butter . . . . 1 part. Beeswax . . . . 1 " Soapstone . . . . 1 "	264	Works badly in both machines.
Cocoa butter . . . . 1 part. Beeswax . . . . 2 parts. Soapstone . . . . 1 part.	167	Works tolerably in the machine.
Spermaceti	454	Works well in both machines.
Spermaceti . . . . 3 parts. Stearine of lard . . . . 1 part. Soapstone . . . . 2 parts.	70	Works very well in both machines; next to bayberry and graphite (old lubricant.)
Spermaceti . . . . 3 parts. Stearine of tallow . . . . 1 part. Soapstone . . . . 2 parts.	142	Works well in both machines.
Beeswax	36	Difficult to work in loading machine.
Beeswax . . . . 4 parts. Graphite . . . . 1 part.	136	Difficult to work in both machines.

A statement of the weight of fouling, etc.—Continued.

LUBRICANTS.		FOULING. 100 SHOTS. GRAINS.	REMARKS.
Beeswax Graphite	8 parts. 3 "	209	Same remark as last.
Beeswax Soapstone	4 parts. 1 part.	26	Works rather better in both machines.
Beeswax Soapstone	8 parts. 3 "	58	Same remark as last.
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Beeswax congeals at	141°	"
Japan wax congeals at	101°	"
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COMPRESSED POWDER FOR SMALL ARM AMMUNITION.

Many considerations, existing and prospective, have rendered it desirable that the effect of compressing the charge of a small arm cartridge, so far as modifying its performance was concerned, should be thoroughly ascertained. The tendency of the experience of the age toward diminished calibers and high initial velocities renders the question of length of charge, under such circumstances, one impossible to be left out of account. It becomes of the utmost importance to diminish by all admissible means the disproportionate length of the powder cylinder, as well as to facilitate its ignition. The result of trials already prosecuted had sufficiently indicated that compression of the charge without extra provision for easy ignition was attended with no beneficial results. It remained, therefore, to develop the best system of perforation of the charge at the same time that the effect of different degrees and kinds of compression were undergoing trial.

In arranging a programme for this trial, so that definite conclusions might be arrived at, the following considerations presented themselves:

I. What are the new conditions introduced into the question of small arm ammunition by the proposed process?

II. How can these conditions be best thrown successively into relief in order to determine how far they each influence the result?

In reference to the first question, it is apprehended that the *structural character* of the coherent mass of powder, under various degrees of compression, becomes a prominent subject for consideration. The nature of the agglutination that takes place, the interstitial spaces, with the kind and manner of their filling, whether by the mutual indenting or the breaking down of the grains, are considerations that closely concern the question of ignition, and must largely depend upon the original density of the cake and the degree of elaboration of the granular surfaces.

Dense musket powder, it was observed, might be compressed until its gravimetric equaled its volumetric density, and yet the mass could be plainly perceived to consist of concreted grains, and no doubt differed materially in its properties from a similar mass of unbroken cake. Light "Oriental" musket powder, on the other hand, is so affected by even the slight pressure incident to the loading of the service metallic ammunition that one-quarter of the charge of a carefully emptied cartridge will pass through sieve No. 1. These considerations indicated the propriety of conducting the trials with powders of at least two different original densities, and "Oriental" and "Hazard" were selected as representing:—the one, the lightest and dullest, the other, the densest and most highly glazed of the musket powders which have been deemed admissible to the service.

Following the experiments *pari passu* through every department of the trial and report, will be found two columns devoted to service ammunition, both Hazard and Oriental; the first column recording the performance of ordinary machine-made cartridges of each powder, the second that of cartridges made by hand with accurately weighed charges of sifted powder. The service cartridges are, by this second column, put on the same footing in point of uniformity of charge as the various compressed cartridges, and comparisons can thus be more fairly instituted.

This sheet of tabulated facts, although divested of everything but mere results, and those only of the most essential character, arranged in a manner which appeared to promise the most perspicuity, should yet, in order that it may render up its meaning unequivocally, be analyzed, quality by quality, determining the relative standing of each class of ammunition in each essential quality that has been tested, and assigning to pre-eminence in each desideratum such coefficient of importance as the respective qualities may be deemed entitled to.

In order to avoid unnecessary repetition of descriptive terms it will perhaps be best to characterize the three *kinds of compression* as divisions; the two *kinds of cavity* in each division as classes 1st and 2d of that division, and the four *degrees of compression* in each class as the 1st, 2d, 3d, and 4th degrees.

Confining the discussion for the present to the Oriental series of ammunition, the first general fact that is apparent on inspection is that in the fourth degree of compression in every class the limit of *useful effect has been passed.* The pressures and recoils at that degree of compression are, to be sure, small, but the initial velocities and penetrations are correspondingly trifling, and all exhibit very marked want of uniformity. The mean absolute deviations with this degree of compression, where they could be obtained at all, indicate an utter want of accuracy at 300 yards, with an enormous convexity of trajectory; while at 500 yards no results whatever could be obtained. The fouling, too, in the 4th degree of compression will be observed to be from three to ten times the average amount derived from the other degrees in the same classes. We are thus relieved at the outset from the further consideration of ammunition compressed 0''.3 in length, and have to compare only the first three degrees of compression under each class.

Beginning with the question of INITIAL VELOCITIES, the following facts are substantially apparent: Compared by the degrees of compression the second degree enjoys the pre-eminence in all the six classes; then comes the service cartridge when made by actual weight; then the first degree of compression in all the classes; then the ordinary machine-made service cartridge; and, finally, the third degree of compression in all the classes. Compared by classes, the first class in each division is superior to the second, especially in cartridges of the second degree of compression. Compared by divisions, the first and second are equal as regards the average of all their constituent classes, comparing it, either with the actual density of the powder concerned, or with the gravimetric density of the same powder poured loosely into a measure. The latter course was adopted, not only as furnishing, for a report, the readiest means of mental comparison, but principally because these relative gravimetric densities in "Oriental" and "Hazard" powders preserve the same ratio toward each other through the various degrees of compression, which is not the case when the relation between the gravimetric and actual densities is used. This latter relation, however, can, of course, be instantly deduced for any case, the actual specific gravities of the respective powders being given.

The following table will show the gravimetric densities of both kinds of powder for the various comparisons used, and the percentages of compression from the volume of loose powder. Sifted and gauged powder only has been used throughout, the charges being in every case carefully weighed.

	ORIENTAL.		HAZARD.	
Actual specific gravities	1.6919		1.7736	
GRAVIMETRIC DENSITIES.	Ounces.	pr. ct.	Ounces.	pr. ct.
Loosely poured	880.1	0	912.4	0
Thoroughly shaken down	1049.8	16	1089.0	16
As existing in service cartridge powder space, 0″.248122	1114.3	20	1114.3[*]	18
Compressed and perforated, but length of charge not reduced	1279.7	31	1322.3	31
Compressed 1″ in length and perforated	1402.8	37	1453.7	37
Compressed 2″ in length and perforated	1552.0	43	1608.3	43
Compressed 3″ in length and perforated	1736.8	49	1799.8	49

The compressions were thus carried to a point where the gravimetric and volumetric densities were about equal, the volume being reduced nearly one-half from that of loose powder.

Oriental musket being the powder now, and for some time past, used in the fabrication of metallic cartridges at this post, it was determined to use that powder for the first series of trials, running through every permutation in degree of compression, direction of compression, and kind of cavity or perforation; and a second series, to be fired with Hazard powder, omitting the repetition of such portions of the first programme as the practice with Oriental had demonstrated to be entirely valueless. The trial has been extended to all the characteristics of the ammunition which could be tested at this post, and the results will be found on the appended table.

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[*] This is on the assumption that each kind of *service* cartridge has received 70 grains of powder in fabrication. A loading machine, however, that would put 70 grains of Oriental in a case, would insert 73 grains of Hazard, giving volumetric density 1162, with 19 pr. ct., &c.

Following the experiments *pari passu* through every department of the trial and report, will be found two columns devoted to service ammunition, both Hazard and Oriental; the first column recording the performance of ordinary machine-made cartridges of each powder, the second that of cartridges made by hand with accurately weighed charges of sifted powder. The service cartridges are, by this second column, put on the same footing in point of uniformity of charge as the various compressed cartridges, and comparisons can thus be more fairly instituted.

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2d DIVISIO

PERFORATED.

ressed ″.	Compressed 0.2″.	(
7	43	
7	43	
1¼	28¾	
¼	28¼	
13	1223.83	
48	1150.73	..
0	4.0	
5	1.7	..
917	10,500	
071	9,666	..
6	5.4	
1	5.2	..
.78	13.47	
.35	10.97	..
83	5.8	
54	11.18	..
33	5.5	...
83	6.92	...
33	90.33	
25	84.83	...
5	2.2	
6	0.7	...
509	0.647	
733	0.953	...
508	0.720	...
583	0.738	...
772	1.143	...
725	1.138	...
005	1.262	...
767	1.214	...
284	1.098	...
355	2.100	...
927	1.694	...
89	1.631	....
08	1.285	....
34	1.747	....
56	1.749	....
00	1.594	....
3″	° 43′ 43″	1°
	49 18	....
1	49 9	

though the cartridges of the second degree of compression in the first division rank higher than the corresponding cartridges in the second division. Both these divisions are superior to the third.

Turning now to the PRESSURES, we find, as was to be expected, a certain relation between them and the initial velocities. The numbers indicating the order of merit among the pressures are, of course, in the order of the degrees of pressure, instead of being inverse, as in the case of velocities. Bearing this in mind, we are not surprised to find in each class the second degree of compression characterized by a number indicating generally the highest degree of pressure in its class, the third degree of compression showing the lowest pressure, and the first degree an intermediate one. While, however, the lowest initial velocities correspond to the lowest pressures, the converse is not equally true. Nos. 20, 19, 18, and 17 of velocities have, respectively, Nos. 1, 2, 4, and 3 of pressures; but Nos. 1, 2, and 3 of velocities have Nos. 13, 14, and 12 of pressures, instead of Nos. 18, 19, and 20.

In order, therefore, that pressures and velocities may be properly considered in their respective relations to efficiency, a line in the table has been devoted to the relative merits of the various cartridges as regards the ratio of their velocities to their pressures, No. 1 being the ammunition in which this ratio is the largest. We find the value of this ratio to be substantially in the inverse order of pressures; or in other words, that the pressures increase more rapidly than the velocities, as required by theory.

As *uniformity* in pressures and velocities for any one ammunition is a quality whose consideration is scarcely less important than the pressures and velocities themselves, a line under each of these heads has been arranged to convey some idea in this direction by giving the MEAN VARIATION from its own average exhibited by each variety. This mean variation is, for the purposes of comparison, expressed in percentage of the average to which it refers. Next to giving the entire data from which each average was deduced, this method was thought to give the most satisfactory means of judging of the performance of each class of ammunition, and it has been applied to most of the average results reported.

It will be observed that in uniformity of velocities loose powder is surpassed by nearly every form of compression; that compression at both ends is preferable as a method; that a perforated charge is more uniform than one with a conical cavity; and that a moderate compression gives results superior to one where more force is employed. In uniformity of pressures it is observed that while no marked distinction can be made in favor of any division or method of compression, perforated charges are preferable to those with conical cavities; and the third degree of compression gives, in all cases, the worst results. Hand made cartridges appear, also, to be inferior in this quality to machine made—a fact perhaps attributable to the impossibility of giving the former always the same final compression in closing the cylinder.

Accuracy at 300 and 500 yards is indicated by stating the MEAN ABSOLUTE DEVIATION of three targets of 20 shots each at both ranges with each variety of ammunition, together with their averages. As the element of uniformity necessarily enters into the mean absolute deviation as a function, no separate statement of that quality is furnished. It is seen at a glance that in the matter of accuracy perforated ammunition enjoys a decided superiority in all the divisions; that throughout the best results are obtained with the second degree of compression, and that hand made service stands very creditably.

In regard to flatness of trajectory at 300 and 500 yards, which is indicated in this table, so far as it can be judged by the CORRECTED ANGLE OF SIGHT necessary for attaining a given range with a given ammunition, some curious results are observed. The service ammunition when made by weight holds the first rank at both ranges. With the compressed cartridges the general tenor of the 300-yard results appears to be inverse to the initial velocities, the lower velocities giving the flatter trajectories and *vice versa*, while the 500-yard practice follows the velocities in the first division, and is apparently inverse to them or follows the pressures in the second and third divisions. In fact, the performance as regards angle of elevation at 500 yards in the first division is almost complementary to that of the other two divisions at that range.

In the matter of PENETRATIONS, a good series of each variety of ammunition was fired at short range, (50 feet,) and a few, generally three, shots were obtained with each variety at 500 yards. The target was, as usual, composed of white pine boards 1 inch thick and 1″.25 apart. It is believed, however, that more than usual care was exercised in the matter of uniform thickness, dryness of the wood, and absence of sap, knots, cracks, and open joints.

Perhaps nowhere better than here may the remark, truism as it is, be ventured, that the impression of disparity conveyed by the figures in the lines devoted to ORDERS OF MERIT must, to prevent misleading, be constantly qualified and corrected by reference to the actual records above them from which they are deduced, that a comparatively low place in the order of merit may not be inconsistent with a fair performance in the premises, and that the moderate range of difference manifested in some of the qualities tested may go far to explain a want of strict illustration of theory in the figures indicating the order of merit. Thus the penetrations here indicated relatively, as ranging from one to twenty, were all respectable penetrations between 11 and 14 inches. Even in these small limits, however, some general facts are observable. At both ranges the heaviest pressures give substantially the least penetrations, and the least pressures, combined with the least velocities, give nearly the best penetrations. The hand made service cartridge, which exhibits about the least penetration of any at short range, is next to the greatest at 500 yards, and a general inspection indicates that little can be predicated for either range from observations on the other.

The RECOILS were taken with a simple spiral spring apparatus, which gave very uniform results for each variety of ammunition. It is believed that for purposes of comparison they will be found entirely reliable, although, owing to the increase in virtual weight of the piece, they are, as a whole, probably below the actual recoils. They are least with the greatest compressions, and follow somewhat the pressures and inverse velocities.

The FOULING of the various styles of ammunition was determined by weighing the piece to one-tenth of a grain before and after each series of twenty-seven shots; six such targets for each variety of ammunition furnished the averages given in the table. From these it at once appears that the deposits of fouling in all classes increase quite rapidly with increased degrees of compression.

Thus far in the discussion of the figures in the table the results obtained with Oriental musket powder only have been considered. A parallel system of trials with Hazard musket powder will, however, be observed on the tabular statement. This comparative series is complete in the matters of initial velocity and pressure, while in the other qualities tested the comparison has been confined to the second division only, or cartridges compressed from the rear.

This "division" appeared, from the experiments with Oriental powder, to afford the most promising field for results favorable to compressed ammunition, and was thus selected as the first for prosecuting the comparison between light and dense musket powder; it being the intention, however, to carry that comparison through all the systems of compression, as has in fact been done in the items of initial velocities and pressures. The results obtained, however, in comparing both compressed and service ammunition, made with both the powders in question, soon indicated so distinctly the superiority, in all important particulars, of a light powder over a dense one that it was deemed unadvisable to further protract the trials.

On the whole, it would appear that no very material advantage is gained by the use of compressed and perforated cartridges of musket powder. The reduction in length which was looked for proves to be confined to very narrow limits—the perforation and diminished diameter of cylinder necessary to enter the tapered case taking up much of what is gained by the compression.

The use of compressed charges must necessitate an entire change in the machinery of fabrication. No system which contemplates the compressing of the charge *in* the cartridge case itself can be entertained, as the fulminate, being in position, must occasion frequent and embarrassing, if not dangerous, accidents; moreover, the compression in such case would necessarily be from the front—the direction indicated by trial as giving in all cases the worst results. Should the interior of the cartridge case be made truly cylindrical—the exterior taper being effected entirely by graduating the thickness of the metal—about 0".1 might be saved in the length of the compressed charges, by the insertion of a full sized cylinder being thus rendered possible. This arrangement would also provide at once for the close cylindrical hold of the front of the case upon the ball, doing away with the rather abrupt change in diameter that is now exhibited at that point, which is difficult to preserve concentric in fabrication. It is not believed that the change would involve the necessity of any alteration of the chamber, while the whole cartridge would present a more clean cut and "mechanical" appearance. The ultimate question, too, of how compressed ammunition can be *put together* in the loading machine would be stripped of one of its most embarrassing features.

On the completion of the new arrangements for taking velocities, &c., now in progress at this Arsenal, a series of trials upon finer grained and quicker powders will be pushed to completion. The results, so far, in this direction being too incomplete to be of value, are not embodied in this report.